# MILITARY PHYSICAL ORTHOPÆDICS.

## PART I.

## GUNSHOT WOUND OF NERVE.

ARTHUR STANLEY HERBERT, M.D., B.S., Lond.

1918.

With the Authors
Compliments.

FIG. 1. (*Frontispiece*).—Artificial muscles applied in a case of simultaneous "drop-wrist" and "drop-foot."

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## GUNSHOT WOUND OF NERVE.

BY

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FIGURE 1—FRONTISPIECE.

PRIVATE G.—Shell wound at Gallipoli of left temporal bone; slight fracture; unconscious a few hours; later there was a gradual onset of unconsciousness and right hemiplegia; condition greatly improved after trephining. Date of wound, 28/5/15. Admitted to Rotorua Hospital, 17/7/16.

*Condition on Admission.*—Partial paralysis of right arm and right leg, chiefly of extensor muscles, with some spasticity and tendency to tremor of right hand; slight right facial paralysis; hypoæsthesia of right arm and leg; very sluggish right knee-jerk and plantar reflex; liable to attacks of giddiness and vomiting; purulent discharge from left ear.

*Treatment.*—Farado massage; extensor glove; calliper; long elastic strap. Wearing this apparatus as a permanent or semi-permanent appliance, patient could walk without a stick, and almost run. The long attachment of the Souttar glove was allowable in this case of permanent paralysis, as a little stretching of the extensors was of minor importance.

# INTRODUCTORY REMARKS.

By Surgeon-General R. S. F. Henderson, C.B., K.H.P.

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Military orthopædics may be defined as the study and treatment —preventive and curative—of bodily deformities resulting from, or likely to result from, wounds, injuries, and disease incurred in war.

In order to achieve the best results from orthopædic treatment the aid of the physician must be co-ordinated with that of the surgeon; and physio-therapeutics embracing massage, electrical, mechanical, and balneological treatment, combined with functional training in workshops, should supplement operative surgical measures.

The author of this pamphlet may fairly claim to be an expert in the physical as distinguished from the surgical side of orthopædics, not only on account of his many years experience as Superintendent and Government Balneologist of the Rotorua Sanatorium, but from the fact that since the earliest days of the war large numbers of invalided soldiers requiring such treatment have been under his care.

In the following pages he stresses the importance of promoting the voluntary action of partly paralysed muscles by the provision of artificial muscles, and in this way bringing about, to a great extent, the same results as are achieved by the masseur, the battery, and other expensive adjuncts, and so rendering these latter aids in many cases accessory rather than indispensable.

This method of treatment he claims to be simpler, less expensive, and more humane, in that it removes the patient more speedily from the category of invalids to that of fairly useful workers, who, whilst daily gaining health and strength, are at the same time adding to the producing-powers of the manhood of the country.

R. S. F. HENDERSON.

# PREFACE.

THE following notes, the crystallized results of some considerable experience, will, it is hoped, prove of practical use to the general practitioner and to the operating surgeon as well as to the physical-treatment specialist. When war broke out the writer was, and had been for twelve years, in charge of the New Zealand Government Baths and Sanatorium at Rotorua, where an average of 120,000 baths and physical treatments were given yearly.

Realizing the immense possibilities of the place, he suggested to the Government the advisability of utilizing these establishments for the physical treatment of wounded. The suggestion was adopted; the Sanatorium (Mineral-water Hospital) was taken over for military purposes; the resources of the baths, with a large staff of masseurs, were placed at the disposal of the military authorities, and by January, 1916, a new military hospital, the King George V, was erected and ready for use.

This hospital, which, like the Sanatorium, is built with the semi-open-air wards, stands on an ideal site amidst park-like surroundings, on the sunny slope of a hill overlooking a large lake; and at the moment of writing there are in the two hospitals about 250 patients undergoing physical treatment.

A special feature of the hospitals, in addition to their open-air character, is that the treatment is *ambulatory;* practically no patients are in bed—all are out whenever possible in the sunshine and fresh air.

Even such cases as paraplegia from gunshot wound of the spine are "up and about" out-of-doors in wheeled chairs or litters. All cases are under active physical treatment with baths, massage, electricity, or, pending the completion of occupational workshops, such light occupations as basket-making and wood-carving; and in the intervals of treatment outdoor games of all sorts are provided, so as to minimize the tendency of long-drawn-out and tedious cases to get "stale." As P.M.O. of these two hospitals the writer has had an almost superabundant clinical material to draw upon; and if the results of his experience as here set forth appear some-

what scrappy and disjointed, the engrossing routine of duty must be advanced in excuse.

When a wounded man is discharged from hospital, further active surgical treatment being deemed inapplicable, he is often in somewhat sorry case and urgently in need of further medical assistance. It is here that the practice of physical treatment comes in, and as nearly every medical man in every country will be called upon to deal with these cases, either in his private practice or in hospital, the subject of physical treatment becomes lifted from the somewhat narrow sphere of the specialist to one of general interest. It behoves every medical man, therefore, to possess himself of such knowledge of what may be termed physical orthopædics, in contradistinction to operative orthopædics, as will enable him to deal adequately with military orthopædic problems hitherto unfamiliar, and at first sight puzzling.

It is hoped, too, that these notes may serve in some small way to remind operating surgeons of the very serious deformities, and consequent delay in the restoration of function, that may occur if they do not impress upon patients leaving their hands the necessity of immediate, and possibly long-continued, use of supporting-apparatus after operations such as suture of certain nerves.

Simplicity is the essential point in orthopædic apparatus, and there is nothing in the following pages abstruse or complicated—nothing that could not easily be evolved for himself by any practitioner having the time.

Everybody, however, has not the time or the bent for inventing new appliances, finding out their weak points, and correcting his failures; and it is with the view of presenting for consideration a selection of appliances which have stood the test of actual use in a very large number of wounded cases that this book has been written.

When first confronted with the problem of treating multitudes of crippled and disabled men the author used the ordinary methods of massage, electricity, exercises, baths, and douches. It was soon found, however, that these methods, if they were to be made successful, required, in a large proportion of cases, supplementing by apparatus affording mechanical support to paralysed muscles. To meet necessities a system was evolved of special splints and rubber muscles, first described in the *New Zealand Medical Journal*, December, 1916.

At that time the author was under the impression that he had hit upon something new, but, like most inventors, he soon learnt that there was nothing new under the sun !

One essential point however is, I believe, new, and it is the basic idea underlying the whole system of treatment here advocated, and that is the use of rubber as an *active* elastic force by harnessing it to, and diverting the energy of, a non-paralysed muscle, instead of using it in a passive sense as a mere elastic ligament.

However that may be, with the exception of the glove for musculo-spiral paralysis, every piece of apparatus here figured has been devised by the writer and made by the hand of the local saddler and the local motor mechanic ; and the plea is advanced that therein lies a certain recommendation—for so simple is the apparatus, and so easy of construction, that, given a piece of elastic, there is hardly a place in the civilized world where a wounded man wearing one of these appliances could not get his apparatus repaired or replaced, and at a cost of only a few shillings.

This volume deals exclusively with the consideration of the later results of gunshot wound of nerve trunks, as, apart from their extreme importance as a class, these cases have constituted an overwhelming majority of those requiring physical treatment ; and it deals with them primarily from the point of view of *treatment.*

As attention has thus been focussed on practical treatment rather than on any theoretical considerations, the usual, and perhaps more logical, arrangement of a text-book has been departed from, and except in the first chapter the grouping has been in terms of convenience of treatment rather than those of anatomy—in fact, this professes to be a note-book only, rather than a text-book.

Little attempt has been made here to collate the writings of others, and this is practically a record of personal experience. Working, as it were, in a watertight compartment remote from other orthopædic hospitals, and thrown almost entirely on one's own resources, one is apt to get into a narrow groove ; at the same time, the writer dares to hope that this very insularity of position may have evolved ideas which contain some germ of originality.

A. S. H.

June, 1918.

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* Photographs by Newman, Rotorua.

## APPENDIX I.



## APPENDIX II.

# MILITARY PHYSICAL ORTHOPÆDICS.

## CHAPTER I.

### PHYSICAL EXAMINATION.

The term "physical orthopædics" is here used in contradistinction to "operative orthopædics," and may be held to cover the utilization of all physical means, except operation, for the prevention or correction of deformities and for the restoration of lost muscular function. The ideal treatment should be preventive—that is, should foresee and forestall the formation of any deformity; unfortunately, however, it is in reality more often corrective, and is concerned with the reduction of a deformity which has been permitted to occur.

In military surgery this resolves itself, in the vast majority of cases, into the effort to restore function to muscles after gunshot wound of nerve, and physical orthopædics is complementary to operative surgery.

Physical treatment may be pre-operative or, more often, post-operative—that is, it may be used to increase the vitality of damaged tissues in preparation for an operation, or it may be employed to coax back vitality and function after gross lesions have been repaired by operation and the parts placed in such a position that restoration of function becomes physically possible. In a third and very important class of cases it replaces operation altogether.

The original idea of orthopædics was rather the correction of deformity than the restoration of function; but, with time, the latter aim has grown steadily in importance, and, in war surgery, with the exception perhaps of certain plastic operations about the face, the idea of restoration of function has become paramount.

In reality, however, the two aims are identical. Every part of our body is made of a certain shape to subserve a certain purpose, and the more perfectly that shape can be restored the more likelihood there is of perfect restoration of function. We thus arrive at one of the cardinal rules of treatment, that *reduction of deformity must precede restoration of function.* This is not a rule to be taken with slavish literalness—for instance, in correcting a deformity it may be necessary temporarily to overcorrect it, and thus produce an artificial deformity—but in the main it holds good.

As pre-operative cases constitute such a small proportion of the whole, it is assumed in these pages that every case coming for treat-

ment has passed finally out of the hands of the surgeon and has been sent on for physical treatment. The surgeon, then, having already dealt with the nerve trunk, in almost every case the task set before us is the restoration of function to *muscle*. On this we must concentrate our attention, and all other matters are but subsidiary, and merely means to an end. For reasons that will become apparent later, in the vast majority of cases it is the *extensor* muscles only that have to be considered.

**Examination of Patient.**

The importance of the most extreme care in examination cannot be overestimated. This may sound a truism, but it may be remarked that, while in ordinary medicine the most careful examination may only point to probabilities, in military orthopædics this is almost always replaced by a certainty. Given a knowledge of anatomy, and sufficient patience and care on the part of the investigator, a definite and accurate diagnosis can nearly always be arrived at; and—again a truism—an accurate diagnosis is necessary for accurate treatment: there are no placebos in military orthopædics.

The patient is now examined according to the following headings:—

**Posture and Gait.**

The first glance at the patient will often reveal important lesions; and here I would remark that, while of course it is necessary in very many cases to examine the patient stripped in bed, important points in treatment as well as in diagnosis may be overlooked if the patient is not also examined up and dressed, and there are advantages in this latter examination preceding the former.

Thus a man limps into the room with feet everted and toes pointing out, complaining of pain about the internal lateral ligament of the knee and perhaps effusion into the joint. Seen first in bed, attention is focussed on the knee-joint; seen up, the characteristic gait suggests that perhaps valgus pads on the soles of his boots may remove the abnormal strain on his knee-joints. The mechanical stress being removed, the secondary traumatic arthritis recovers instead of being treated ineffectually for rheumatism.

Again, a man in heavy army boots catches his toes on the floor. Examined in bed, unburdened by boots, the slight paresis of the dorsiflexors of his foot may pass unnoticed. Most important of all, however, the degree of disability can be roughly assessed under normal "up and dressed" conditions, for in orthopædics one must always think in terms of function.

**Deformity.**

In quite a large proportion of motor-nerve lesions the resultant deformity is so pronounced and characteristic that a rough diagnosis

can be formed at the first glance. Thus, in the arm, the musculo-spiral lesion with its dropped wrist and fingers, the ulnar with its *main-en-griffe* and the hollow between the metacarpals of the thumb and forefinger, and the median with its concave palm and concave flexor surface of the forearm, can hardly be overlooked. In the leg we have the wasted quadriceps (more often due to joint than nerve injury), the dropped foot of anterior tibial, and the inverted foot of musculo-cutaneous lesions as especially prominent. The special deformities of individual lesions will be dealt with fully later.

**Muscular Paralysis.**

Paralyses are generally obvious from the resulting disability and deformity. The individual muscles are examined electrically, and—what is generally a matter of at least equal importance—groups of muscles are tested as a preliminary measure by manual examination.

This physical examination is not a haphazard affair, and should be carried out carefully and scientifically with a mental vision of the dissected muscle before the eyes of the operator, and an appreciation of certain fundamental rules of muscular mechanics. One of the most important of these is Hunter's *Law of the Minimal Load.* This is well exemplified by the action of the deltoid.

With the arm hanging at the side the deltoid may appear to be completely paralysed ; passive elevation of the bent elbow from the side may enable what is only a partially paralysed deltoid to raise the arm a little farther, as it is acting at a greater mechanical advantage ; while, on the other hand, passive elevation of the arm with the elbow extended may still find the deltoid apparently paralysed, for the pull of the deltoid tendon is close to the shoulder-joint fulcrum, while the weight of the forearm is on a long lever far from the fulcrum. The most crucial test, however, is to eliminate altogether the weight of the limb. Thus, in testing the dorsiflexors of the wrist in wrist-drop, the hand is placed with its ulnar border resting on a table, and the operator's finger placed under the patient's wrist as a pivot. The forearm flexor muscles are tested by the dynamometer or by a hand-squeeze ; the flexors and extensors of the elbow, wrist, and knee by resistance against the examiner's hand ; the calf-muscles by flexing the ankle, placing the palm of the hand against the patient's sole, and telling him to extend his foot at the ankle ; the dorsiflexors of the foot by laying the patient on his sound side, with the knee of the injured side slightly flexed, and the internal malleolus pivoted on a support.

Again, the fibres of an apparently paralysed muscle may be seen, or felt by the hand, to contract although there is no resultant joint-movement. This is especially true in muscles unable to exercise their function through overstretching rather than through true paralysis.

Finally the *muscular tone* is roughly assessed by direct palpation and by the completeness of the flaccid deformity. Muscular hypotonia indicates nerve-interruption, muscular hypertonia nerve-irritation. *Contracture* means a hypertonia gradually merging in fibrosis and pointing to nerve-irritation, especially neuritis, to injury rather than division.

**Electrical Reaction.***

As this book is concerned primarily with treatment, the subject of electrical reaction will be touched on only lightly here, and the reader is referred to the standard text-books on neurology for fuller details.

In all electrical testing it is essential that both the skin of the patient and the electrodes should be warm and moist, and that the strength of the current should be under perfect control.

1. Each suspected muscle is tested first with the faradic current, via nerve. A large flat "indifferent" electrode is placed on some convenient part of the body away from the lesion; the small "active" electrode is applied to the "motor point," the spot at or near the entry of the efferent nerve into the muscle, at which contraction of the normal muscle is most easily stimulated. If contraction of the muscle occurs we know that the motor nerve is still capable of function, and treatment by faradic current—*e.g.*, farado massage—can be prescribed.

2. If the muscle does not react, or reacts but feebly, to the faradic current it is tested with the galvanic current applied direct to the muscle. Two methods may be used, the unipolar or the bipolar. In the former, and usual, method the indifferent and active electrodes are placed exactly as in faradic testing, in the latter both electrodes are placed as nearly as possible directly on the muscle; and the current is made and broken by a mechanical key electrode, or, if that is not available, by lifting and replacing one electrode. The current is measured through a milliampèremeter, or, roughly, if a battery is used, by reading off the number of cells used by the switch. Normally, muscle responds more easily to the cathode, and at the moment of closing or making the current, a result symbolized by KCC > ACC. It may be found that ACC > KCC (a polar or qualitative change), or that an abnormally large current is required (a quantitative change), and that the contraction of the muscle is feeble, slow, and vermicular. This constitutes the *reaction of degeneration* (R.D.), and indicates—

(*a.*) That the lesion may or may not be recoverable:
(*b.*) A lesion either in the anterior cornu or the motor nerve (lower motor neurone):

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* *Cf.* Appendix II, p. 129.

(*c.*) That treatment by the faradic current—that is, via a nerve which does not conduct the impulse—is useless, and that treatment must consist in keeping up the vitality of the muscle by its direct stimulation by galvanic current.

*Partial reaction of degeneration** means diminished response to faradism and sluggish reaction to galvanism, with ACC > KCC. It indicates—

(*a.*) A partial lesion of the peripheral motor neurone (anterior cornu or nerve):

(*b.*) Treatment by both faradic and galvanic current, the proportion of faradic to galvanic being in inverse ratio to the severity of the lesion and the amount of R.D.:

(*c.*) As a rule, and except in very early stages, a relatively good prognosis.

Or, finally, the muscle may respond to neither faradic or galvanic current. This indicates—

(*a.*) A bad, but not necessarily a hopeless, prognosis:

(*b.*) Very prolonged and patient treatment:

(*c.*) Assuming that the question of immediate operation has already been considered and rejected, operation if three months' treatment gives no result.

3. The muscle may be tested by Lewis Jones's condenser apparatus, a method in substitution for and preferable to the ordinary galvanic-current test. The measurements are made in microfarads, and the process is less painful, more rapid, and more precise.

4. In doubtful cases, in which all other stimuli fail to produce any effect, the test of *reaction of degeneration at a distance* (R.D.d.) of Ghilarducci may be applied.†

It is claimed for this test that it will sometimes show that a muscle which fails to respond to any other stimulus is yet contractile, and that if this test is negative the muscle is entirely cut off from its trophic centre.

The indifferent anode is placed over the upper part of the back, while the active cathode is applied distal to the muscle to be tested —*e.g.*, at the wrist of the forearm-muscles—and the contraction is obtained on closing the current.

## Anæsthesia.

An accurate mapping-out of the areas of anæsthesia is essential for accurate diagnosis. It is important, moreover, not only that they should be defined accurately on the patient's skin, but that they should be charted accurately, for a subsequent variation of the chart may have important bearing not only on the prognosis, but on the

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* This term must not be confounded with the *reaction of incomplete division* an early change, in which faradic reaction is lost, there is easier response to galvanism than normal, KCC > ACC, and the muscular contraction is comparatively brisk. It means division or degeneration of some axis-cylinders of the nerve, and not of all.

† *Cf.* Fig. 9, p. 130.

diagnosis. The patient's eyes should, of course, be closed during the examination.

The sensibilities to be noted are—

(*a.*) *Epicritic*—that is, the recognition of light touch (such as a camel-hair brush to the skin), of slight differences of heat and cold, and of localization (distance of compass-points). As a rule, epicritic sensation is " first to go and last to return."

(*b.*) *Protopathic*—sensibility to pin-prick and extremes of heat and cold. This sensation generally returns before epicritic in recovering cases.

(*c.*) *Deep sensibility*—that is, to pressure of a blunt point. A pin-prick is recognized as a pressure and not as a prick. The term includes joint-sensation, muscle-sensation,* and vibration-sensation. It has nothing to do with the skin, and may be present in absolute cutaneous anæsthesia. Its loss is obviously a symptom of grave significance, except in functional cases.

A convenient and easy method of marking out the area of anæsthesia is to take a sharp-pointed pen dipped in ink, and, starting at the centre of the anæsthetic area, to prick out radiating lines of dots—of course, without piercing the skin—until a sensitive spot is reached. The peripheral dots are then joined by an inked line. The diagram here given shows radial anæsthesia mapped out in this way.

Method of marking out Area of Loss of Protopathic Sensation.

* Muscles have two kinds of sensation—that of pain, loss of which causes muscular analgesia; and muscular sensibility, or sensation of active contraction, loss of which is a factor in ataxia.

The area of anæsthesia having been demarcated, it is compared with—

(*a.*) The area of cutaneous distribution of a peripheral nerve :

(*b.*) The segmental or root area in lesions suspected of being in or near the central nervous system.

The area of anæsthesia is also correlated with the distribution of muscular paralysis. As a result we may deduce whether one or more nerves are affected, and sometimes the exact site of the lesion.

Should the area not correspond with the anatomical distribution of a nerve, this may be due to several causes :—

(1.) Functional paralysis ; and it must be remembered that this is frequently combined with an organic paralysis.

(2.) Some fibres only of the nerve may be degenerated.

(3.) Some fibres only may have recovered.

(4.) In some areas—*e.g.*, the back of the hand—the anatomical distribution of the cutaneous nerves varies very considerably, especially in regard to the anastomoses between separate nerves. Care must be taken in these areas not to make too hasty deductions.

(5.) Malingering.

## Paræsthesia.

" Pins and needles," itching, &c., generally betoken an incomplete nerve-lesion, and especially neuritis. An excessively painful variety, " causalgia," is, in my experience, most frequently met with in the median nerve and the sciatic branches.

## Trophic Changes, Tropho-neuroses.*

These, while generally very obvious, may, or more often may not, assist in localizing the lesion. Sometimes the trophic disturbance marks out with absolute accuracy the cutaneous distribution of the affected nerve, but more frequently it is very much more widely distributed. The whole structure of a hand or foot may be affected in severe cases; but the skin-tissues show trophic disturbance in almost every case of wound with incomplete division of the nerves of the limbs, and, indeed, in a great many cases with no wound

* Trophic disturbances are generally regarded as characteristic of nerve-irritations, and as rare in complete nerve-division. I have, however, seen profound trophic changes in cases in which several inches of nerve have been shot completely away.

of any important nerve, these latter cases being due to toxic neuritis.*

The usual trophic changes—glazed skin, ridged nails, dripping-wet hands, and so forth—are too familiar to merit description. Some tropho-neuroses, however, while fully as common, are not so generally recognized. One of these is what I term "raindrop" palm. This is an exaggeration of what is, in many persons, the normal mottled appearance of the palm. In a large proportion of cases of wounds of the arm, the skin of the palm and palmar surfaces of the fingers and thumb is mottled with pale evascular areas, apparently around the mouths of the sweat-glands. It is as if drops of rain had washed the colour out of the skin wherever they had chanced to fall. As a rule, these areas are quite flush with the surrounding skin; but in one of my cases they were distinctly acuminate, and, as the condition improved, desquamation of the spots occurred, and they became flat, pale, evanescent areas, as in the ordinary raindrop cases. These spots generally occur thickly scattered over the palm and flexor surfaces of the fingers and thumb, without regard to nerve-distribution (Fig. 2, page 61); but that they are very distinctly related to the nerve-supply, and are tropho-neuroses, is seen from the fact that frequently they are confined strictly to the area supplied by the affected nerve, and that they come and go, deepen and fade away, while being watched, like the blush on the cheek of a nervous youth.

A very curious point about the erythema is that its area of distribution is sometimes inverted—that is to say, in ulnar paralysis the median area only may be "raindropped," and in median paralysis the ulnar. Further investigation has shown the explanation of these inverted cases. In all of them it is due to the superimposition of a second tropho-neurosis, "glossy skin." The whole palm is affected by the "raindrop" phenomenon, but in the paralysed nerve area the "glossy skin" condition has masked or prevented the "raindrop."

## Reflexes.

A normal reflex indicates, of course, the integrity of the reflex spinal arc, and its absence indicates that there is a lesion or loss of function somewhere in that circuit. A routine examination of the chief reflexes is useful, not only because it narrows down the possible location of injuries, but because it may reveal unsuspected lesions.

The reflexes are superficial and deep or tendinous. Presence of a superficial reflex shows that the circuit of afferent nerve, spinal centre, efferent nerve, and muscle is intact; its absence does not necessarily indicate any serious trouble, but absence of a deep reflex

* Compare also "Angiotic Paralysis," p. 24.

would point to an organic lesion. The following table* gives a list of the principal spinal reflexes with their root origin :—

| Reflex. | Spinal Nerve. | Deep or Superficial. | Remarks. |
|---|---|---|---|
| Elbow-jerk .. | C 5, 6, 7 .. | D. | |
| Scapular reflex .. | C 5, 6, 7, 8; D 1 | S. | |
| Epigastric reflex .. | D 4, 5, 6, 7 .. | S. | |
| Abdominal reflex .. | D 8, 9, 10, 11, 12 | S. | |
| Cremasteric reflex | L 1, 2, 3 .. | S. | |
| Knee-jerk .. | L 2, 3 .. | D. | May require reinforcement. Absence may mean lesion in the lower or peripheral motor neurone (anterior cornu or anterior crural nerve) or in quadriceps. Exaggeration may mean upper neurone lesion, or be of no significance. |
| Gluteal reflex .. | L 4, 5 .. | S. | |
| Ankle clonus .. | L 5; S 1 .. | D. | Usually organic disease of cord. A pseudo-clonus may occur in neurasthenia. |
| Ankle-jerk .. | L 5; S 1 .. | D. | |
| Plantar reflex .. | S 2, 3 .. | S. | Absence means lesion of lower motor neurone (anterior cornu; sciatic nerve) or directly damaged muscle. Dorsiflexion of toes (Babinski) points to central organic lesion (upper cortico-spinal neurone). A condition of "pseudo-plantar reflex," in which stimulation of the sole causes a massive clonic flexion of the whole limb, is often seen in neurasthenics and wounded men with spinal irritative symptoms. |

## Diagnosis.

The general methods of examination of the patient having been considered, the diagnosis becomes a question of *where* is the lesion and *what* is the lesion ?

The former question is readily answered, within certain limits, by the application of ordinary anatomical knowledge, and will be discussed in detail, together with the appropriate treatment, in the next chapter, when considering the lesions of individual nerves. The latter resolves itself into the inquiry as to whether there is a macroscopic or microscopic organic lesion or a functional disturbance of the nerve, and, if the former, what is the degree of the lesion.

The following classification† of nerve-trunk wounds will assist :—

* According to Dana.

† The classification adopted is based on that of Colonel Purves Stewart and Captain Arthur Evans in their work, "Nerve Injuries and their Treatment."

(*a.*) *Complete Division.*—

Absolute paralysis of the muscles supplied by the nerve.
Absolute anæsthesia of the area supplied by the nerve.
Complete R.D. after about a week from the time of the injury.
Trophic changes sometimes, especially if the case is seen at a late stage. (*Cf.* footnote, p. 17.)

(*b.*) *Partial Division.*—

Partial or no paralysis.
Partial anæsthesia: loss of epicritic sensation, protopathic present or absent.
Causalgia (sometimes).
Paræsthesiæ (generally).
Trophic disturbances (nearly always).
Reaction of incomplete division (early stages).
Incomplete R.D. (late stages).

(*c.*) *Contused Nerve.*—

As this lesion may vary in severity from the lighest to the severest degree, the symptoms will vary correspondingly.

(*d.*) *Compressed Nerve* (*e.g.*, Crutch Paralysis, Pressure of Callus, &c.)—

Symptoms vary with the degree of compression. In mild cases paræsthesiæ are prominent; in severe cases the symptoms would be those of complete division; in callus cases they may be ingravescent.

(*e.*) *Concussed Nerve* (nerve not directly injured; no macroscopic changes)—

Paresis rather than paralysis; incomplete anæsthesia; usually normal electrical reactions.

There remain the consideration and elimination of cases of malingering and of functional paralysis.

**Malingering.**

Malingerers, happily, have usually neither anatomical nor physiological knowledge, and can therefore readily be caught out by the flagrant conflict of symptoms with anatomy. The paralysed muscles may not conform to any nerve-distribution, or, if they do, the area of anæsthesia may not coincide. In rare cases, where the paralysis and anæsthesia correspond, an electrical test of the supposedly paralysed muscles will quickly detect the fraud.

In testing the anæsthetic area in malingering the "Yes–No" method is useful. The examiner demands, "Say 'Yes' if you feel it, and 'No' if you don't," as he probes the blindfolded patient vigorously with a pin. Unless a malingerer is very wide awake, he is apt to be caught by saying "No."

**Functional Paralysis.**

These cases are not uncommon, and are of extreme interest. As a rule, large groups of muscles are involved, and the anæsthesia also runs in large well-defined areas not corresponding with the nerve-distribution to the simultaneously affected muscles, or to any nerve. Thus the whole arm may be paralysed and anæsthetic, with a sharp horizontal line at the shoulder marking the limits of the anæsthetic area, the " glove " or " stocking " type of anæsthesia. Such a paralysis could only be caused by enormous damage to the brachial plexus or by a central lesion, and in neither case would the area of anæsthesia correspond. The anæsthesia is generally very complete, and may include epicritic, protopathic, and deep sensation, all ending at the same sharp line; but often epicritic sensation is present while protopathic is lost. There is sometimes also a boundary zone of hyperæsthesia.

The electrical reactions of the muscles are normal, and the deep reflexes are present, and may be exaggerated. It is important to distinguish functional paralysis absolutely from malingering. While malingering may be defined as a deception practised by the conscious ego, functional paralysis is a deception by the unconscious ego: the conscious patient is quite honest.

It is extremely important also to remember that very frequently indeed functional paralysis is something superadded to an organic lesion, and this lesion may easily be overlooked. Thus I now have under my care a soldier admitted with paresis* of the left arm and leg and total left hemi-anæsthesia. A sharp line of demarcation ran from the crown of his head, down the centre of his nose, and so down to his symphysis pubis. His sole only was sensitive. There was also some slight aphasia, and the condition started with a " stroke." I classed the case as purely functional until it was pointed out to me that the right side of the tongue was paralysed, and I began to think that there might be an underlying central lesion. A few weeks later the patient developed pyrexia and a systolic mitral murmur. He then had a second " stroke," with difficulty of deglutition, and complete aphasia, and the mitral murmur disappeared, to return a week later.

The diagnosis would appear to be loose mitral vegetations of low infective power, an infarct of the lower part of the pons, crossed paralysis, with superadded functional hemi-anæsthesia, further growth of vegetations causing a bruit; these swept into the blood-stream, causing loss of bruit and a second " stroke," and again fresh vegetations on the valve.†

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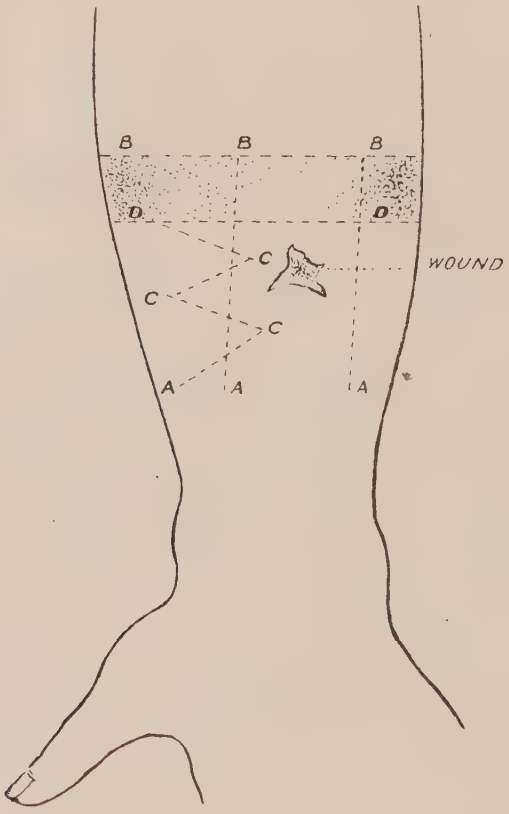
* This case illustrated to perfection a form of intention tremor said to be pathognomonic. On being told to move his hand the patient appeared to make frantic efforts to do so, with consequent wide oscillatory tremor of the forearm, due to contraction of the antagonistic muscles.

† As a sequel the aphasia and other functional symptoms suddenly cleared up, the organic symptoms remained.

The commonest type of functional paralysis, however, is this next case. The patient had a small bullet wound of the forearm involving the median nerve. There was paralysis of all the muscles of the hand, ulnar as well as median, and complete stocking anæsthesia up to a line 2 in. above the wound. Under treatment the stocking anæsthesia gradually receded, and finally true median paralysis and anæsthesia remained.

The case was interesting as illustrating to perfection the " zigzag test " for functional anæsthesia, and incidentally for malingering. This consists in an attempt to deceive the subconscious ego, or the conscious one, as the case may be. The patient's eyes are closed, and the limit of anæsthesia, BB (see diagram), is defined by the straight




Zigzag Method of testing Anæsthesia in Functional Cases.

lines of pin-pricks beginning at A and ending at B. This limit defined, the pin starts again at A and zigzags up through the points C, thus passing over a much longer part. In functional cases frequently, and often in malingerers, consciousness is deceived, and the line of anæsthesia moves down nearly an inch to DD.

Another method of examining hysterical anæsthesia is that of Babinski. The patient is not told to say when he feels a prick—indeed, the suggestion of anæsthesia should be carefully avoided—but he is told to point at once with his finger to the site of the prick.

Roussy and Boiseau* claim that by this method they have never yet found anæsthesia in any case of psycho-neurosis "that had not previously undergone medical examination," and declare that hysterical or pithiatic anæsthesias are the result of medical suggestion.

Another type of neurosis frequently met with is functional tonic spasm, a good example of which is seen in Figs. 43 and 44. This spasmodic contracture is frequently extremely difficult to overcome, and has to be treated by suggestion combined with mechanical reposition. For this latter a fixed rigid splint is generally necessary in the early stages, to be succeeded later by elastic tension. The advantage of the latter is that it may often be arranged so as not to interfere with voluntary movement of the part.

Thus, in a case of bullet wound of the base of the thumb, the latter was firmly and immovably adducted, apparently by dense adhesions. I quite took the view that the contraction was due to the obvious fibrous tissue, until one day in an unguarded moment I easily abducted the immovable thumb. The contracture, however, returned as strongly as ever, and the thumb had to be kept abducted in an aluminium palm-splint. Later this was replaced by a modified Souttar glove with a thumb-piece only, thus giving the patient full use of the hand, which is now slowly recovering.†

## Fallacies.

Finally, in making a diagnosis, certain pitfalls and fallacies have to be guarded against. Because a man has a gunshot wound of a limb, and paralysis of muscles, anæsthesia, trophic changes, R.D., and other signs of degeneration in a nerve trunk, it does not necessarily follow that the symptoms are due to direct wound of the nerve, or even are in any way at all connected with the wound. Thus a man with wound of the thigh may also have drop-foot from alcoholic neuritis. Such a condition would usually be obvious by evidences of more widespread neuritis.

## Ischæmic Paralysis.

More important cases are those of ischæmic paralysis. It has long been recognized that the continued pressure of tight bandages and splints may interfere seriously with the nutrition of a nerve trunk, more especially if these are applied to a limb infiltrated with effused blood, which subsequently organizes, becomes fibrous, and contracts around the nerve. Such cases are usually readily treated by removing the cause, and by promoting local circulation and nutrition by massage and electricity.

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* "The Psycho-neuroses of War."

† These two cases would be classified by Babinski as "reflex paralysis."

**Angiotic Paralysis.**

Another paralysis of vascular origin, which closely simulates a nerve-lesion, has recently been described under the name of "angiotic paralysis."

Wounds of arteries, especially in the upper extremities, without corresponding wounding of nerve trunk, may be followed by paralysis, anæsthesia, trophic changes, and R.D. Some of these cases obviously belong to the class of ischæmic paralysis already considered ; in others, in which there is incomplete blocking of the vessel, it is suggested that the paralysis is reflex or due to ischæmia of the nerve-terminations.*

**Localized Neuritis.**

A peripheral nerve passing closely adjacent to a septic cavity—*e.g.*, a bone sinus—may become infected, and the resulting neuritis may be so severe as to cause paralysis. Under such circumstances the suspicion may arise that the nerve has been divided. It is necessary to bear such cases in mind, as treatment must be directed not to the nerve, but to the sinus. The neuritis will generally recover as the sinus is cleared up.

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* Captain Burrows, B.M.J., 1918, i, 199–203. Desplats et Buquet, Rev. de Med., Paris, 1916, xxxv, 578–619.

# CHAPTER II.

## BATH, ELECTRICAL, AND MASSAGE TREATMENT.

### Treatment.

The special treatment of paralysed groups of muscles by temporary or permanent artificial substitutes is dealt with in the next chapter; the routine treatment by massage, electrical means, and baths is dealt with so fully in so many excellent text-books that it is unnecessary to go over the ground again here. It will suffice to summarize the main essential headings.

### Massage.

This may be "plain" massage by the masseur's hands alone; may be given in combination with a douche, as in Aix massage, where the force and temperature of the douche supplement the masseur's fingers; may be mechanical, in the form of vibration; or may be combined with electrical treatment in farado massage. The essential object of massage of muscles is to promote local nutrition by stimulating the local circulation, and by the same means, and by movements, to break down adhesions and to promote their absorption.

### Electrical Treatment.

While this is too large a subject even to summarize in a paragraph, it may yet be defined under a few headings. It may be used for relief of pain, or to maintain the function of muscles.* For the first purpose we generally use either large anodal currents, very finely interrupted secondary currents, or counter-irritate with high-frequency currents; or, finally, by ionic medication, drive in some drug, such as sodium salicylate.

For the second purpose we use the faradic or sinusoidal current, if the efferent nerve is functioning. Lately the Bristow condenser battery has largely superseded these. When the physiological continuity of the nerve has been interrupted we apply the constant current direct to the muscle, and the method of choice is through the dipping metronome interruptor.

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* Whether the passage of an electric current along the course of a damaged nerve has any direct action in hastening the regeneration of the nerve, and apart from any action on muscle, as was once generally assumed, appears now to be a matter of considerable doubt.

Recently, in cases showing high degrees of R.D., I have obtained most promising results by utilizing the R.D.d. of Ghilarducci (see p. 15, also Appendix II).

The electrodes are applied in the same manner as for testing, but the current passes through a metronome interruptor, precisely as in ordinary "interrupted galvanism," or the cathode may be carried centrifugally from one end of the muscle to the other.

**Diathermy.**

This method of treatment raises the temperature of the deep tissues in any selected zone of a limb. It is recommended in painful neuritis and in ischæmia with fibrous transformation. It would appear to have a promising future, but requires some considerable caution in handling.

**Radiotherapy.**

In the treatment of causalgia radiotherapy has given satisfactory results, applied direct to the nerve or to the roots and spinal ganglia.

**Baths.**

The proper use of baths for physical treatment requires a whole book to itself alone. It would be of little general interest to describe the special methods in use at Rotorua, as, in the first place, many of them are the result of taking advantage of local peculiarities and would be inapplicable elsewhere, and, in the second, this book is intended primarily for general use by medical men not having baths at their disposal.

Baths may be used essentially for the following purposes :—

(1.) For relief of pain by means of a warm bland environment; and here it must be remarked that many cases of causalgia are exacerbated by warmth, and incidentally by fine weather :

(2.) For causing hyperæmia, active or passive (see p. 60), and thereby promoting nutrition and increasing metabolism :

(3.) For softening tissues, either directly or in preparation for the masseur :

(4.) As a form of massage in the shape of douches, whirlpool baths, &c. :

(5.) As a sedative in large immersion-baths at the indifferent temperature (say, 87° F. to 94° F.) :

(6.) In the form of the warm swimming-bath, as a means of enabling exercise of muscles and joints to be taken by crippled limbs. The weight of the patient is removed, and more movement is possible in a warm bland medium.

**Ice and Cold Water.**

Though not strictly within the scope of this volume there may be pointed out here, while on the subject of hydro-therapeutics, the extreme value of cold precordial packs in many cases of "D.A.H.," especially cases of tachycardia. If ice is available it is broken up by a needle into fragments the size of a hazel-nut, placed in a sponge-bag, and applied over the heart with an intervening layer of flannel. The patient should be semi-recumbent, and the bag so slung as not to press heavily on the chest-wall. The pack should be left on about twenty minutes, and the spot then covered with a piece of warm flannel. As a general rule, a rapid pulse will drop down some five to ten beats, but maybe much more, and an intermittent pulse become steadier.

The astonishing point, and one for which I attempt no rational explanation, is that a too slow pulse will often quicken to normal.

Should ice not be available, four folds of linen wrung out of cold water, and covered over all with a layer of dry linen, will serve the purpose, but this pack is not so potent in action as the ice-bag.

One other useful application of the ice-bag is in hyperthyroidism. It is not unusual to meet with symptoms of hyperthyroidism in cases of shell-shock; some enlargement of the thyroid may or may not be present, exophthalmos also is not infrequent, while, of course, palpitation and tachycardia are usual. An ice-bag over the heart, with another on each side of the thyroid over the arterial supply, will often yield most gratifying results.

# CHAPTER III.

## ARTIFICIAL MUSCLES.

### Principles of Treatment.

The physical treatment of muscles paralysed by gunshot wounds is based on the same principles as that of infantile paralysis. When once this elementary idea is grasped and carried to its logical conclusion, methods of treatment forthwith become clear, and suggest themselves, as difficulties arise, with almost automatic precision. There is nothing new in the axioms here laid down, but as one finds them ignored not infrequently, it would seem that no further excuse is needed for restating them.

1. *The paralysed muscle must never be allowed to be stretched*, and, when possible, its origin and insertion should be approximated by posture.*

2. *The muscle needs a period of absolute rest;* but this period must not be too prolonged, or stagnation of circulation and retardation of recovery ensue. The stage at which absolute rest should cease is a matter of personal experience, and each case must be judged on its merits, but I am confident that very many more cases are given too long rather than too short absolute rest. One sees the results plainly enough in fracture cases, boxed up in hermetically sealed plaster-of-Paris, and, on a larger scale, in patients kept too long in bed. Rest should be rhythmic rather than continuous—should be, so to say, *clonic* rather than *tonic*.

3. *The circulation through the muscle should be stimulated.* At first this must necessarily be brought about by *passive* measures, such as massage, muscular contractions induced by interrupted galvanism, passive movements, local heat, baths, or alternations of constriction-passive-hyperæmia (the so-called Bier's hyperæmia). In recovering stages it may be much better brought about by *active* use of the muscle, an auto-massage of the intramuscular vascular system outrivalling any passive measures.

4. *The continuity of the nerve-supply must be established.* By no possible means can the continuity of a completely divided nerve be *restored*. The most we can do is to place the nerve in such a position as will enable the re-establishment of continuity to be a physical possibility, and, this having been done, to ensure that it is placed

* In the practical application of this rule one must not be bound too slavishly. Thus too persistent use of a cock-up hand-splint may paralyse the opposing flexors; and herein lies one advantage of elastic splints.

under the conditions most favourable to its vitality and growth. The former task is that of the operating surgeon, the latter that of the physical orthopædist. The surgeon can bring the divided ends together, but, as has been shown by Langley,* owing to the distortion of the nerve-pattern he cannot even secure the exact apposition of corresponding nerve-bundles; later on the physical treater must ensure, not only the most favourable general conditions, but the maximum available local nutrition.

The question arises whether the artificial contraction of paralysed muscles and the forced concentration of voluntary effort to cause natural contraction have any direct effect in hastening the regeneration of nerve-fibres. In a partially interrupted nerve they undoubtedly do so; but whether this is wholly by indirect nutritional means, or whether there is in addition a direct, and what might be termed trophic, influence on the nerve-fibres, is a question, I believe, not yet fully answered.

5. *Voluntary and normal use* of the muscle-nerve-central-nervous-system chain must be encouraged. This is the basic idea of the system of treatment advocated here, and its performance is made possible by the system of rubber artificial muscles described in the following pages, and utilized at the Rotorua Military Hospital for the past three years.

No special originality, of course, is claimed for this idea; it has forced itself on the independent perception of orthopædic workers the world over.† The special feature of the Rotorua system is the method which has been adopted to make the idea feasible—namely, the duplication of paralysed muscles by rubber ones—quite a different matter, as will be seen later, from the use of rubber *supports*.

## General Treatment.

Let us take the case of a nerve damaged by gunshot wound. The case has passed out of the hands of the operating surgeon, all wounds are healed, but the muscles supplied by the nerve are paralysed, and there is an area of corresponding anæsthesia and analgesia.

There are three factors to be taken into consideration: the patient, the nerve, and the muscles.

The general health, physical and mental, of the patient must be maintained at the highest possible pitch. The man has passed through the strain and fatigue of a campaign; he has been shocked by the infliction and affliction of his wound; and he has been debilitated, as a rule, by a prolonged stay in hospital and by repeated operations.

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* "On the Separate Suture of Nerves in Nerve Trunks," Langley, B.M.J., 12th Jan., 1918.

† "The keynote of treatment is that some form of active exercise should be prescribed at the earliest possible moment, and should be steadily progressive."—"Organization and Methods of the Military Orthopædic Hospital, Shepherd's Bush."

His new surroundings should be made as cheerful as possible; he should be, as far as can be arranged, remote from suggestions of operations and the atmosphere of an ordinary hospital; he should have the maximum of sunshine and fresh air, and be given a good nourishing and appetizing diet. At the same time his recreation should be catered for, and he should be encouraged to do things for himself, and not to look upon himself as a chronic invalid.

The treatment of the nerve is practically that of the muscles. While every precaution is taken to prevent stretching of the part by posture and supports, the voluntary use of the affected limb—that is, the passage of normal impulses down the nerve—should be encouraged at an early date; while, if the nerve conducts, daily treatments are given with gentle faradic or sinusoidal currents.

The treatment of the affected *muscles*, however, is the crux of the situation. To ensure their continued contractility they are treated daily with interrupted galvanism or the Bristow battery; they are massaged, and, when possible, as here at Rotorua, are made hyperæmic with hot mineral-water baths and douches.

But the keynote of the whole treatment is *voluntary normal use* of the muscles. If this can be obtained, not only is the ideal recuperative agent employed, but a most economical agent, which to a very great extent replaces the masseur, the battery, and the bath. Employing this agent, the patient can be discharged at an early stage to his own home, where he can be usefully employed, with a certainty that repair will be slowly progressive. Of course, if he remains in hospital his progress will be more rapid—at any rate, at first—for he will have the added stimulus of ordinary physical treatment. But the point I would emphasize is that this latter treatment is *accessory* and not essential.

The question naturally arises, "How is voluntary muscular contraction to be utilized when the muscle is paralysed?" Of course, if the muscle is absolutely paralysed the question is unanswerable. In such a case we can only follow out the rules laid down in axioms 1, 2, 3, 4. In a very large proportion of cases, however, the muscle is not really *absolutely* paralysed, although it may appear to be; and, when the requirements mentioned in these axioms have been complied with, many a muscle that would otherwise be condemned as lost, and which consequently would inevitably become lost, will show feeble signs of contractility. We must nurse those first few feeble contractions, and gently coax the muscle back to life again. Also, we must catch those first feeble contractions at the very beginning, for every normal contractile impulse, however feeble, that passes down paves the way and deepens and broadens the path for its successor.

Our problem, then, is—

(1.) To catch the first contraction—therefore the apparatus must be applied from the first, even though the muscle shows no sign of voluntary contraction:

# CORRIGENDA.

Page 31.—*For* "No muscle contracts without a simultaneous contraction of its antagonizing muscle,"

*Read* "No muscle contracts normally without a contraction of its antagonizing muscle."

(2.) To prevent the atonic muscle from stretching—therefore a support is necessary :

(3.) To rest the feeble muscle, but rhythmically, so as to avoid stagnation—therefore a rigid support should as far as possible be avoided :

(4.) To keep up the nutrition of the muscle by physical treatment.

Clearly, then, some form of elastic support is indicated, and this I very early adopted ; and it has been largely adopted elsewhere, probably on the same line of reasoning. But this at best is but a passive support, and it was only later that the idea dawned on me of an *active* elastic support as an agent to wheedle, as it were, the first feeble contractions out of a muscle.

When a paralysed muscle is duplicated by a parallel elastic support we get an illustration of the " law of the minimal load." All weight and strain are taken off it, and it is placed in the position already quoted of the dorsiflexors of the wrist in wrist-drop when the hand is resting on its ulnar border. More than that, however—for, if the elastic support is taut, it continues to assist the efforts of the contracting and shortening muscle.

The next law to remember is that *no muscle contracts without a simultaneous contraction of its antagonizing muscle.* This is well seen in peripheral paralyses. Thus if the extensors of the fingers are paralysed, forced attempts at voluntary extension will cause flexion of the fingers ; and again, paralysis of the extensors weakens the flexors. I believe this law to be responsible for much of the therapeutic efficacy of voluntary muscular effort, especially when artificial muscles are being used.

**Artificial Muscles.**

We have seen that a paralysed muscle may be duplicated by an elastic band, but this is a mere elastic support. If, however, the band is attached to an opposing muscle that *normally always acts simultaneously with the affected muscle,* we convert our inert mass of rubber into a living thing, an artificial muscle ; and if by a system of reflexion or deflexion we can harness this artificial muscle to pull in the same direction as the paralysed one, our task is completed.

In some regions the problem is simple ; in others it is, for all practical purposes, impossible ; but luckily, in the most common lesions of the nerves of the limbs—that is, in paralysis of the *extensor* muscles—the problem is extremely simple.

Elastic support, then, may be used in two different ways—as an elastic splint or artificial *ligament,* or as an artificial *muscle.*

**Elastic Splints or Ligaments.**

In cases of drop-foot it is customary to support the foot by leather straps attached above to a short calliper and below to the sole of the boot. These straps may well be replaced by elastic bands in part of their length, as certain definite advantages are attached to a non-rigid support. Thus, while stretching of paralysed muscles is still prevented, a certain small but very useful movement is allowed in the ankle-joint, in the tendons as they run through their sheaths, and in the muscles themselves. This slight movement, by preventing stasis, improves the local circulation and nutrition, and prevents adhesions. One frequently sees a foot which, on removal from a fixed support, remains unsupported at a right angle and no longer drops: in other words, there are sufficient adhesions of the tissues about the ankle-joint to overcome the pull of the weight of the foot, and the foot feels and looks partly devitalized. In a similar foot treated by elastic support mobility and vitality are greatly preserved.

When a limb is confined by a fixed splint the tendency of the muscles is to resign themselves gradually to the inevitable—to cease, as it were, to kick against the pricks—to lie more and more quiescent, and gradually to atrophy. Indeed, we utilize and encourage this tendency to muscular indolence by a policy of passive resistance in the splint treatment of inflamed joints. If, however, we employ elastic splints, the natural contractile tendency of the muscles is encouraged. It is as the difference between the heavy and cruel hand of a bad rider on the rein and the gentle yet effective " feeling the horse's mouth " of an expert.

In succeeding pages a variety of uses for similar elastic support is suggested (*cf.* Fig. 3 *et seq.*).

Another sphere of usefulness of elastic support is in the breaking-down of adhesions. Thus Fig. 3 shows a very simple and effective elastic sling* which is invaluable in cases of stiff but not ankylosed elbow. Every step taken by the patient causes a slight up-and-down movement of the forearm, which is accentuated by the elastic support. Quite considerable degrees of elbow-mobility can be obtained by this method, which has the great advantage of long-continued action.

Another valuable application of elastic traction is shown in Fig. 42, where it is used to cause gradual extension of the knee-joint in a case of sutured sciatic. The leg had to be flexed to allow of nerve-suture, and the flexion remained permanent. Anything but the most gentle attempts at extension caused incipient gangrene of the toes, but by the gentle continuous pull of the elastic bands the knee was extended to 170°.

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* Since writing this I have learnt that the elastic sling has been used by MacEwan and others for years.

Again, elastic traction is particularly useful in contractures. A good example is shown in Fig. 45, which shows a most obstinate and inflexible hysterical contracture of the hand, consequent on gunshot wound of the arm, being gradually overcome.

**Elastic Artificial Muscles.**

Elastic bands attached to normal muscles not only act as supports, and so present all the advantages already discussed of elastic ligaments, but can be made to reflect the power of these muscles so as to replace or reinforce the action of muscles paralysed or partly paralysed. It is in the lower extremity that these artificial muscles are most useful; and one simple invention, the "long quadriceps strap," has revolutionized the treatment at Rotorua of gunshot wound of the leg, and has enabled results to be obtained which would otherwise have been quite unattainable.

In the first place it has enabled treatment from the first to be *ambulatory*. The beneficial effects, both physical and mental, of taking a patient off crutches and enabling him to walk about with rubber muscles, frequently without even the aid of a stick, are really quite remarkable. At once there is the mental exhilaration of being able again to walk in a fairly normal manner; the general health, the appetite, the circulation at once improve. And with the improvement of the general circulation there is, in recovering cases, the improvement in the local circulation in the affected muscles through auto-massage of the local blood-vessels.

The conditions are strictly analogous to those governing the physics of varicose veins of the legs, where "standing still is worse than walking."

Then we have the added effect of the "law of antagonizing muscles" (p. 31), as well as of the "law of the minimal load."

Every time that a step is taken the normal contraction of the flexor muscles sets up a contraction in the partly paralysed extensor muscles, and this "suggested contraction" is utilized to the full if there is the faintest possible nerve conductivity and the faintest possible flicker of contractility in the muscle. Furthermore, the action is repeated rhythmically and unconsciously over prolonged periods. Finally, while stretching of the muscle is guarded against, the minimal-load law comes into play; for not only is all weight lifted from the muscle load, but owing to the elastic nature of the tractor, the lifting-action is smooth and continuous, not only at the beginning of muscular contraction, but throughout the whole period during which the muscle is contracting and shortening.

**Mechano-therapeutics.**

As the same principles apply, in my opinion, to treatment by exercises and mechanical apparatus, it is convenient to discuss here the question of their use.

For precisely the same reasons that rubber muscles should be preferred to fixed splints whenever a choice is possible, useful occupation, such as is provided in a workshop, and especially interesting and profitable occupation, is preferable as a rule to mechano-therapeutics.

At first sight one is captivated by the idea of relying on the extremely ingenious machines now on the market for the treatment of stiff joints and weakened muscles. I have used a variety of orthopædic machines in a very large number of cases of wounded soldiers, and, while acknowledging their great utility in selected cases, my experience is that their scope of usefulness is distinctly limited.

*Passive* mechanical movement I prescribe but rarely, as, unless used with extreme caution, very serious damage may be done by a mechanical force which it is difficult to gauge, and whose strength is liable to be underestimated. *Active* movements—that is, mechanical forces, such as pendulum action and weighted-lever action (Fig. 58) set in motion and controlled by voluntary muscular efforts of the patient—are much safer, and suffice in all but exceptional cases. Even here, however, I have so often seen old septic trouble lighted up again that I never use even active machine movement except in selected old-standing cases.

The important point emerges that the physical treatment of wounded can be carried out in the majority of cases *with a minimum of apparatus*, and that the absence of expensive mechanical adjuncts is not such a serious handicap. A complete modern outfit is of course an immense advantage; but given a competent masseur, a constant-current battery, a faradic coil, and a few splints, straps, and elastic bands, there are few cases (in which recovery is possible) which cannot be treated successfully, and even in hopeless cases much may be done to minimize the disability.

### Rubber Muscles as a Temporary Therapeutic Measure.

This is by far the most important use to which rubber muscles can be put. While the usual electrical, massage, and bath treatment is being carried out, a therapeutic action, quiet, unobtrusive, almost unnoticed, but none the less potent, is also being continued by the rubber muscle. In recoverable cases the convalescence is immensely shortened—and all at the expense of a few yards of webbing and a few inches of rubber.

### Rubber Muscles as a Permanent Apparatus.

Cases in which the nerve-supply or the muscle has been damaged beyond all hope of repair can be greatly relieved by the judicious adoption of artificial muscles. A limb so treated becomes closely analogous to an artificial limb, but, in the majority of cases, an artificial limb with a natural living framework such as no surgical-

limb maker can ever hope to rival. Thus the useless arm shown in Fig. 4 still possessed a perfectly normal hand at one end of it and normal shoulder-muscles at the other; only in the mid region did it become an artificial limb when fitted with a rubber biceps. Again, a man with permanent drop-foot, wearing a "long quadriceps strap," may have artificial dorsiflexor action of his ankle-joint, but all the rest of his limb is normal.

The rubber, of course, loses its elasticity and wears out in time, but experience has shown that it has a life period of many months, and it can be easily and cheaply renewed. There is, moreover, one very encouraging feature about this line of treatment. Not once, but many times, have I fitted a man up, as I thought, permanently, with artificial muscles, only to find after a few months that the replaced muscle, which by all ordinary tests was pronounced dead, had begun to show signs of renewing vitality; and so an apparatus originally applied as permanent has become a temporary and therapeutic measure.

**The Application of Rubber Muscles.**

It is a very noteworthy fact that in wounds, as in infantile paralysis—and, indeed, as in most forms of paralysis—it is the mechanically weaker extensors that are affected rather than the flexors.

The central idea of some systems of physical development—namely, "stretch," that is, use the extensors—is recalled at once to mind, together with the advice that if you look after the extensors the flexors will generally look after themselves. That, in disease, paralysis of the extensors should occur more readily than that of the flexors* is a readily conceivable proposition, but that the same relative frequency should occur in bullet wounds is a phenomenon which I must confess was at first to me inexplicable. And yet, in my experience, extensor paralysis is overwhelmingly more frequent than flexor. A little consideration, however, will show why, for anatomical reasons, this should be so.

To take the arm: the nerves most exposed to injury are the musculo-spiral and ulnar; the former supplies, except for the supinators, almost wholly extensor muscles, and in the case of the latter the extensor-acting interossei are more important than the ulnar flexor muscles, and even the ulnar thumb-adductors are also extensors (see p. 54).

In the leg the sciatic and anterior crural nerves are those most frequently wounded; and again, for some reason which I cannot

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* *Cf.* Head and Riddock, "Brain," 1917–18, xl. In complete division of the cord, *flexor* movements were the only primary motor reactions. Also Hughes, "Anomalous Musc. Action in Nerve Injuries" (B.M.J., 29th June, 1918), on the preponderance of flexor action in lesions of the upper motor neuron.

fathom,* in wounds of the main sciatic trunk the external popliteal fibres are damaged infinitely more frequently than the internal popliteal. The only flexor muscles supplied by these nerves are the calf-muscles, from the seldom-damaged internal popliteal division, and the hamstrings, from branches arising high up in the sciatic notch, and so generally escaping injury.

As it is in the lower limbs that artificial muscles are most frequently needed, and it is here, too, that the results are most satisfactory, let us consider the case of the legs first.

## Artificial Muscles of the Leg.

For reasons already given, in the leg it is nearly always the extensor muscles that are at fault. I have never yet, amongst over two thousand cases, had to supply artificial flexors of the knee.

Paralysis of the hamstring muscles alone could only occur from a wound very high up in the thigh of the sciatic branches to these muscles without injury to the main sciatic trunk or to the anterior crural. If these latter nerves were also affected artificial muscles could not be applied : they would be *elastic ligaments* only, not muscles. For one cardinal fact must be borne in mind : the contractile power of a band of rubber is, of course, purely passive. To convert it into an active force the rubber must be stretched by an opposing active live muscle ; the rubber then works by reaction. It is no use from a dynamic point of view to apply rubber extension tendons in a case of musculo-spiral paralysis if there is also median-nerve paralysis, nor, as I have seen done, to apply elastic dorsiflexors of the ankle in foot-drop in combination with similar elastic substitutes for paralysed calf-muscles. Such an arrangement constitutes an excellent elastic *splint*, but, dynamically, it is like trying to raise oneself by pulling on one's own heel-tags.

## The Long Quadriceps Strap.

Paralysis, permanent or temporary, of all or any of the muscles of the front of the thigh and leg—that is to say, all the most common paralyses of the leg—may be met by the use of this strap. It takes the place of the quadriceps, of the tibialis anticus, of the extensor longus digitorum, extensor proprius hallucis, and of the peroneus longus and brevis. It is indicated, therefore, in at least 90 per cent. of all wounds of the great sciatic nerve. Fig. 5 explains its general construction and action.

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* Near the fibular head the external popliteal is of course more exposed, but the curious point is that in G.S.W. of the sciatic trunk it is very frequently only the external popliteal fibres that are involved. The division of the sciatic trunk is sometimes very high up, and Langley has pointed out (B.M.J., 12th Jan., 1918) that certain branches run an isolated course, bound up with the main trunk but not *in* it.

Essentially it consists of a Sam Browne of webbing from which is suspended a long band, attached below to the boot. The upper part of this band is of webbing, corresponding to the tendinous "origin" of the muscle; the mid portion is a strong piece of elastic webbing—the muscle proper—merging below in a "tendon" of plain webbing, which ends in a bifid leather attachment sewn to the welt of the boot opposite the metatarsal heads—the "insertion" of the muscle.

The length of the actual elastic portion may vary, but about 6 in. is usually sufficient, and the length of each limb of the bifid strap must be made adjustable by a buckle. Should the strap show any tendency to slip off the front of the patella it may be retained in place either by circular band above the knee or, better, by a knee-cap (Fig. 7), with a loop in front to hold the long strap in position. A loose adjustable circular band around the ankle completes the outfit, which, by the way, is practically hidden by the trousers.

Various complications of simple extensor paralysis may be met by slight modifications of the apparatus. Thus, in peroneal paralysis the outer strap is tightened. Fig. 8 shows a case of quadriceps paralysis, with hyperextension of the knee-joint from stretching of the posterior ligament and of the anterior crucial ligament. A lateral splint with a check hinge-joint prevents hyperextension and lateral wobbling, while the long quadriceps strap supplies extension in the usual way. In all ordinary movements the operation of the long strap is merely an elastic reaction consequent on the pendulum motion of the limb, of the flexor muscles of the knee, and of the calf-muscles; but there is a reserve power behind, which is called into requisition automatically for more powerful movements, or on fatigue, and this reserve power may, if necessary, be increased by fastening the waist-belt to the back trouser-buttons. This reserve power lies in the powerful back-muscles, more especially the glutei and the erectores spinæ.

The apparatus may then be considered as a great muscle, whose origin is the gluteus maximus and spinal erectors, and whose lon· tendon is reflected over the shoulder, passes down the front of the thigh and leg, and is inserted into the forepart of the foot. No better power could be harnessed for our purpose.

**Quadriceps Paralysis.**

Paralysis of the quadriceps from direct wound of the anterior crural nerve is not so very common. I have also had to treat it in several cases of partial hemiplegia from gunshot wound of the head (Fig. 1—frontispiece), and at the moment of writing am treating with double elastic straps a case of gunshot wound of the spine with paralysis of the extensors only of both legs.* More frequently, however, the quadriceps is suffering either from atrophy from wounds

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* *Cf.* footnote, p. 35.

of the knee-joint or from temporary paralysis from overstretching. Patients sometimes arrive on crutches with the *bent* leg suspended by a bandage slung round the neck. In such cases the long-continued overstretching of the quadriceps, as a result of the faulty posture, has resulted in the partial atrophy and almost complete paralysis of the muscle. No cases react more quickly and dramatically to treatment. The limb is straightened, a "long elastic strap" applied, and frequently the patient is able to get about at once with one stick instead of with two crutches, while the recovery of the muscle starts at once.

**Wound of the Great Sciatic Nerve.**

*Diagnosis.*—The symptoms of wound of the sciatic depend upon the site of the lesion and the completeness of division. The general electrical and other reactions of nerve-lesions have already been considered (p. 14), and there is no need to detail them again in connection with individual nerves. A brief summary only of symptoms will be given.

*Anæsthesia.*—The whole limb below the knee is anæsthetic, with the exception of the long saphenous area on the antero-internal surface of the leg, inner ankle, and internal border of the foot, and the small sciatic area, which runs in a strip down the back of the calf for a longer distance than is generally realized. On the outer side of the leg anæsthesia often ends several inches below the fibular head, the external cutaneous supply reaching lower than generally depicted in the text-books.

*Paralysis.*—In complete lesions near the sciatic notch the knee-flexors* are paralysed, except the gracilis and sartorius, and all the muscles below the knee. In incomplete division the fibres of the internal popliteal generally escape, and we get symptoms of external popliteal paralysis.

*Treatment.*—(Henceforth the treatment by artificial muscles, splints, and supports alone will be considered, the general directions for electrical and massage treatment having been already considered.) As already seen, in the vast majority of cases the flexor muscles are rarely affected alone. When they are affected it is almost always in a case where there has been complete division of the nerve, and all the muscles below the knee are then paralysed *en masse*, and artificial muscles are therefore not very satisfactory. Even in such cases, however, the long quadriceps strap may be very usefully applied. This is seen not only in gunshot wounds, but very noticeably in infantile paralysis.

The patient is fitted with a long walking-calliper—modified Thomas's knee-splint—the end of which is passed from side to side through the heel of the boot. This horizontal bar is pivoted or fixed immovably to

* The origin of the nerve to the semitendinosus is sometimes especially high up, and this muscle may escape in otherwise complete sciatic lesions.

the heel, according to circumstances—that is, as to whether a movable or fixed ankle is desired. If the calf-muscles are paralysed the ankle should be immobilized. The long strap is fixed to the boot in the ordinary way, and the patient's power of progression with crutches is very greatly improved. Indeed, in the first case which I fitted up in this manner the patient after two weeks broke his calliper playing golf, to the astonishment and indignation of the splint-maker.

**External Popliteal Nerve.**

The muscles, or the muscle groups, may all be paralysed, or, in incomplete division, a group may be picked out in apparently erratic fashion. The dorsiflexors of the foot may alone be paralysed, causing pure drop-foot; or the peronei alone, causing inverted foot; or both groups may be affected, causing drop-foot with inversion.

*Diagnosis.*—The only point of importance is to determine whether the lesion is or is not above the bifurcation of this nerve into musculo-cutaneous and anterior tibial. Lesions of the main trunk are,—

*Anæsthesia.*—Dorsum of foot and toes and lower three-quarters of fibular area.

*Paralysis.*—Tibialis anticus, extensor longus digitorum, extensor proprius hallucis, and the peronei. There is therefore drop-foot, with inability either to invert or evert the foot. In complete voluntary extension there is some inversion of the foot, with inward pointing of the toes, from the action of the tibialis posticus. (See Fig. 9.)

*Foot-drop with Inversion.* — When both groups of muscles are paralysed, the long strap, but with shortened outer bifurcation, is applied, the degree of shortening being adjusted to meet individual needs. In some cases, however, the ankle is so "wobbly" that some rigid support is necessary. Here a short calliper with hinged ankle-joint is used, with elastic support drawn tighter from the outer limb of the calliper. This arrangement may profitably be combined with a long strap, as the latter both acts as an artificial muscle and takes the weight of the calliper from off an already weakened leg.

**Musculo-cutaneous Nerve.**

*Diagnosis.* — From external popliteal by the absence of anterior tibial paralysis. The foot is inverted.

*Anæsthesia.*—Practically as for external popliteal. The sensory areas of the foot, like those of the dorsum of the hand, are, however, somewhat variable, owing to anastomoses and variable distribution of cutaneous nerves.

*Paralysis.*—Peroneus longus and brevis. There is therefore inversion of the foot (Fig. 10); and, on extension, the great toe is pointed inwards (Fig. 9).

*Treatment.*—Long quadriceps strap, with tighter outer band to foot.

**Anterior Tibial Nerve.**

*Diagnosis.*—From external popliteal by absence of paralysis of the peroneus longus and brevis; there is simple drop-foot without inversion, and on attempted dorsiflexion of the foot it is everted by the unopposed action of these muscles. The toes are kept flexed and cannot be extended.

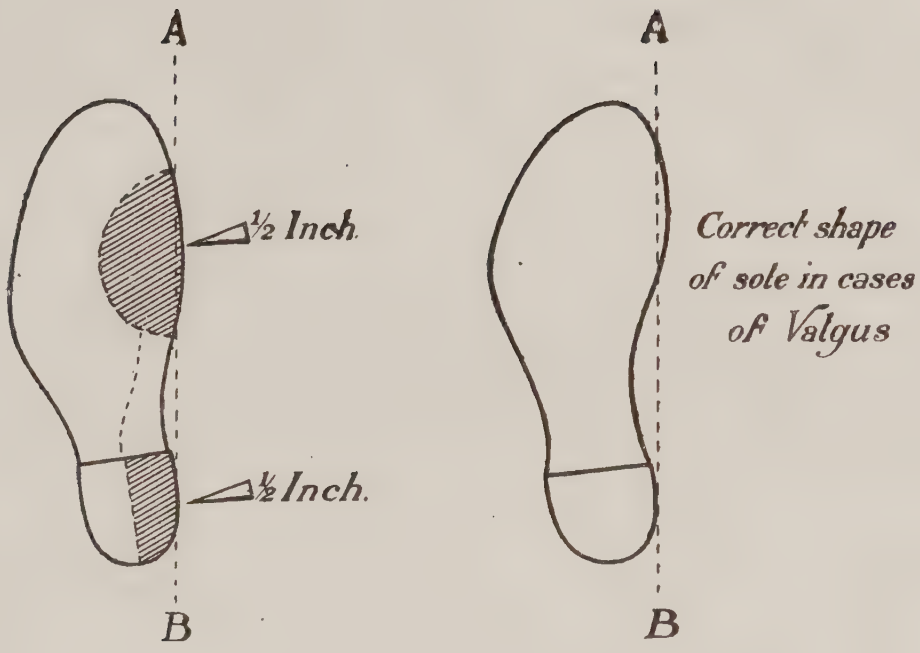
*Anæsthesia.*—The only part supposed to be supplied exclusively by this nerve is a small triangular area in the first dorsal interosseous space. For reasons already given this may or may not be anæsthetic.

*Paralysis.*—Tibialis anticus, extensor longus digitorum, extensor proprius hallucis. Sometimes the extensor proprius hallucis is alone affected, and occasionally the tibialis anticus, in lesions low down or in branch injuries.

*Treatment.*—Simple drop-foot may best be treated by the long quadriceps strap. Wearing this apparatus, all patients at once discard crutches, and may even dispense with a stick. It is customary to equip these cases with a boot having a long back-piece extension up the calf, and two straps or sometimes elastic bands to hold up the foot, or with a boot with a "drop-foot tongue." All these appliances it will be noted come under the heading of *passive* supports. The difference to be noted immediately on substituting the *active* rubber muscle must be seen to be appreciated. A word of caution, however, must be added. A drop-foot patient wearing a long quadriceps strap holds his foot perfectly supported only when in the erect position: if he sits down and crosses his knees his foot tends to drop. It is necessary, therefore, either to warn the patient never to cross his knees, or, better, to provide him with a "check-strap." This simple contrivance consists of a leather anklet to which is attached a small strap with a hook at the end which is caught into the lowest loop of the bootlace.

*Extensor Proprius Hallucis.*—This is perhaps best treated by a short calliper and an internal elastic support (Fig. 13), the long elastic strap being hardly necessary. Sometimes, however, patients prefer the long strap. A strip of adhesive strapping on the dorsum of the toe is also very efficient.

*Tibialis Anticus.*—This muscle is rarely paralysed alone, and then generally by direct injury to the tendon. In such cases there is a tendency to eversion of the foot, with consequent secondary flat-foot. It may be treated in the same manner as the inverted foot of paralysis of the peronei, but with the tension on the straps reversed. Owing to the danger of flat-foot, valgus pads should be placed on the sole—that is, a half-inch wedge under the metatarsal head of the great toe and another under the inner half of the heel (see diagram).




Valgus Boot.

The diagram shows a convenient method of conveying the surgeon's wishes, by prescription, to the bootmaker. The prescriber can thus clearly indicate the thickness of the wedge required, together with the degree of support needed. Thus, as a rule, it is better to apply the two pads (half-inch wedges are an average thickness) without thickening the instep-arch, as the elasticity of the sole is then not impaired. In severer cases the sole-wedge is carried back in a tongue towards the heel, following the contour of the arch of the instep, along the dotted line indicated. In the third degree this is thickened so as to become level with the surface of the heel and to obliterate the cavity of the arch. The line AB should be approximately straight to allow of adduction of the great toe, but not necessarily rigidly straight, as the great toe is usually incapable of full adduction. The straighter the foot along this line the more powerful becomes the instep-arch.

## Bed-boots.

In all cases of drop-foot it is absolutely essential to ensure continuity of treatment. When the drop-foot apparatus is removed at night it must instantly be replaced by a bed-boot (Fig. 15), to prevent the dorsiflexors of the foot from stretching. Again, in patients taking baths, a bath-boot must be worn. This consists of a simplified bed-boot made of stiff canvas, with a sole cut out of thin wood. All leather straps must, of course, be done away with and replaced by stout tapes.

## Internal Popliteal and Posterior Tibial Nerves.

While wound of the external popliteal is exceedingly common, that of the internal popliteal is equally rare. I have not yet met with a single case of uncomplicated internal popliteal paralysis, and only one of the posterior tibial. Also, in incomplete lesions of the sciatic, it appears to be always the internal popliteal fibres that escape.

Complete division of the *internal popliteal* would give posterior tibial symptoms plus paralysis of the gastrocnemius, soleus, plantaris,

and popliteus. The areas of anæsthesia would be practically identical, as the outer side of the foot, the only independent area involved, is supplied through the communicans poplitei to the short saphenous, which receives fibres from the external popliteal via the communicans peronei. At most one would expect patchy anæsthesia. The *posterior tibial* supplies the tibialis posticus, flexor longus digitorum, and flexor longus hallucis. The most noticeable symptom of wound of this nerve, in so far as muscular paralysis is concerned, is the loss of action of the tibialis posticus, so that in voluntary extension of the ankle-joint the toes are pointed outwards and the sole is everted (Fig. 9A)—the valgus position. As, in addition, all the muscles supplied by this nerve support the arch of the foot, there is a very real danger of flat-foot; and treatment must be directed towards preventing this by valgus pads on the sole, with or without an elastic ligament or an elastic muscle attached to the inner side of the sole of the boot. Anæsthesia is confined to the sole of the foot, together with the back of the heel and the dorsum of the ungual phalanges.

**Trunk Muscles.**

Paralysis of the other muscles of the lower limbs and of the trunk is, except as the result of wounds of the spinal cord, comparatively infrequent, and its treatment by artificial muscles need not be considered in detail here. In infantile paralysis, however, such treatment is frequently required, especially for those muscles which serve to maintain the erect posture of the body—viz., the gluteus maximus and the extensor muscles of the spine. Somewhat complicated apparatus is needed in these cases, such as double walking-callipers hinged to a body-frame, and connected to it by strong elastic bands at the back of the pelvis.

**Obturator Nerve.**

Paresis of the adductors of the thigh may be treated by a slight shifting-inwards of the direction of pull of the long quadriceps strap. Indeed, by a little ingenuity on the part of the surgeon this strap may be made to subserve quite a number of purposes. Thus, by altering the direction of pull and by tightening one or other limb of the bifurcation at the boot, it may be made to strengthen either the internal or the external rotators of the hip-joint.

**Nerve Trunks of the Arm.**

The nerves most commonly injured by gunshot wound are the musculo-spiral, ulnar, and median, the first two very much more frequently than the last. Broadly speaking, we look for extensor paralyses from musculo-spiral and ulnar, and flexor paralysis and contracture from the median.

As a rule, the diagnosis may be said to leap into view; but, in any doubt, an examination of the anæsthetic areas of the hand will generally at once determine whether any of these nerves is affected.

A prick over the centre of the pear-shaped musculo-spiral area (see diagram on p. 45), another over the back of the third phalanx of the fore or the middle finger in the median area (Fig. 17), and another over the ulnar border of the little finger in the ulnar area, is a rapid but reliable test; but it must be remembered that a good deal of the remaining territory assigned to the musculo-spiral and median nerves is shifting and unreliable.

**Artificial Muscles—Arm and Hand.**

On the whole, rubber muscles are less satisfactory in the upper extremities than in the lower, and, with the exception of the well-known Souttar glove, apparatus is apt to be unsatisfactory.

**Biceps.**

This muscle may be put out of action by direct injury of muscle or bone (Fig. 4), or, in conjunction with the brachialis anticus, by wound of the musculo-cutaneous nerve. I have had to treat one case of the former and several of the latter during the last twelve months. At first sight it was difficult to see how a rubber biceps could be utilized, but a little reflection showed that if the patient contracted his triceps, and then suddenly relaxed it, the forearm would be flexed by the resiliency of the rubber band. This sounds cumbersome, but in actual practice the patient soon so educated his triceps in its novel duties as to be possessed of a considerable and surprisingly smooth power of flexion. The " origin " of the artificial muscle is an attachment to the back braces*; the rubber band, which needs to be of some length, is then reflected over a smooth protecting moulded-leather shoulder-cap, and is " inserted " into a leather wrist-band. Wearing this apparatus, the patient's flail-like arm became extremely useful, and gradually considerable power of independent flexion returned.

**Musculo-cutaneous Nerve.**

A second case was one of gunshot wound of the arm involving the musculo-cutaneous nerve. The biceps was almost entirely atrophied, and gave complete reaction of degeneration; the outline of the flat brachialis anticus was curiously prominent beneath it, and this muscle retained some power of contraction, owing, of course, to its accessory nerve-supply from the musculo-spiral. There was at the same time anæsthesia of the radial side of the forearm. In this and other cases of musculo-cutaneous injury the major part of elbow-flexion was carried out by the hypertrophied supinator longus. A very simple and useful modification of the artificial biceps is the elastic forearm-sling already mentioned. This consists of a length of rubber drainage-tube tied at one end in a loose loop round the neck,

* A slit in coat admits the strap.

and worn beneath the collar of the coat, and, at the other end, to a leather wristlet. In wounds of the elbow-joint a condition is often met with in which there is movement of perhaps only five or ten degrees, and the arm is perforce carried in a sling permanently. Partly from the fact that the musculo-cutaneous, ulnar, and median nerves all send articular branches to the elbow-joint, but largely from disuse, the flexor muscles of the elbow and forearm will be found often profoundly atrophied. By substituting an elastic for a non-elastic sling, the factor of disuse, at any rate, will partially be done away with, with consequent marked benefit to the muscles. (Fig. 3.)

If a man wearing the drainage-tube sling be watched, it will be noticed that with every step he takes there is a gentle oscillation of the flexed forearm up and down, a flexion and extension of about five degrees. This regular and unconscious movement not only tends to break down adhesions about the joint, but acts as a gentle stimulus to, and auto-massage of, the muscles.

**Musculo-spiral Nerve.**

Owing to the frequency of compound fracture of the humerus from gunshot wound, injuries of the musculo-spiral nerve are very numerous, occurring in my experience much more frequently than those of the median, though perhaps not so frequently as those of the ulnar nerve.* A combination of the musculo-spiral and ulnar paralysis is exceedingly common, while that of musculo-spiral and median is happily comparatively rare. It is possible, however, that data based on larger numbers may modify this impression.

*Diagnosis.*—This is usually simple, on account of the evident wrist-drop. The amount of paralysis and anæsthesia will depend upon the height of the lesion and its completeness. The usual site of the lesion is in the lower third of the arm, above the supinator longus, and, owing to its proximity to the humerus, this nerve is peculiarly exposed to an infective neuritis from a septic compound fracture. Wounds sufficiently high up to involve the triceps are generally those of the brachial plexus affecting the posterior cord.

*Anæsthesia.*—Wounds of upper portion: An area above the external condyle, and another over the middle head of the triceps; also radial area of hand (very various in extent).

Wounds of lower portion: Radial area of hand.

*Paralyses.*—Wounds of upper portion: Triceps (often only partial, as there are many supplying branches†); brachialis anticus (partial only); anconeus; supinator longus and brevis; and the dorsiflexors of the hand, &c.

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* Sir Berkeley Moynihan (B.M.J., 3rd Nov., 1917) gives as a percentage of wounds of all the peripheral nerves—Musculo-spiral, 25 per cent.; ulnar, 24 per cent.; median, 14 per cent.

† I have seen the triceps escape in wounds about the surgical neck of the humerus, involving the musculo-spiral.

Wounds of lower portion: Supinator brevis; extensor carpi radialis brevior; extensor carpi ulnaris; long extensors of fingers and thumb; short extensors of the thumb.*

**Posterior Interosseous.**

Wound of this nerve would give wrist-drop, but no anæsthesia; supination would still be possible to a limited extent,† and slight dorsi-flexion of the wrist with abduction or radial deviation of the hand (the extensor carpi radialis longior is supplied by the musculo-spiral).

**Radial Nerve.**

Anæsthesia of the nerve as shown in the diagram‡ below, and a somewhat varying area of the clefts between, and the dorsum of, the thumb and two fingers and a half.


MUSCULO-SPIRAL (RADIAL) ANÆSTHESIA.

The dotted lines show the area of loss of protopathic sensation in four cases of pure musculo-spiral paralysis. The shaded area marks the common territory where all four areas overlap.

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* The terminal phalanx can usually still be extended by the action of the abductor pollicis and short ulnar thumb-muscles: *cf.* ulnar nerve.

† The supinator brevis is a true supinator; the supinator longus is rather a flexor of the elbow-joint, and not a true supinator. In full pronation it will supinate the arm to the mid position, and in full supination it will equally pronate the arm to the mid position.

‡ The ulnar area shown is that of absolute anæsthesia only.

*Treatment.*—Musculo-spiral paralysis is especially suitable for treatment by artificial muscles, in so far as the hand is concerned.

**Triceps.**

I have failed entirely to devise a satisfactory substitute for this muscle.

**Supinator Longus and Brevis.**

Here again a rubber mechanism is so cumbersome as to be useless.

**Extensor Muscles of the Fingers and Thumb : Dorsiflexors of the Wrist.**

Drop-wrist is one of the commonest deformities arising from wounds. The musculo-spiral nerve may receive direct injury from gunshot wound, but much more frequently it is injured as a result of compound fracture of the humerus, either by direct injury from fragments of bone or by becoming involved in callus. Uncomplicated drop-wrist is one of the lesions that best of all lends itself to treatment by rubber muscles.

It is in this injury, perhaps above all others in the arm, that it is essential that the affected muscles should be prevented from stretching ; and this fact is now so generally recognized that it is hard to believe that at the beginning of the war a large proportion of the cases were put in straight splints. I must confess that in the first few months I noted that all my cases of dropped wrist did badly, and this entirely due to my own neglect of elementary precautions. Arms were taken off the splint and hands allowed to drop during treatment, and patients were not warned that they must keep the hand supinated in washing. Also, in the early splints, while the wrist was kept dorsiflexed, the fingers were not kept extended, and so the extensors were not fully relaxed. One still sees numerous cases put up with a splint reaching only to the metacarpal heads, and these cases often make a sudden progress when the fingers are kept extended.

It is hardly necessary to urge that in the early stages a cock-up splint should always be applied so as to reach as far as the tips of the fingers.* To this rule there are, so far as I am aware, only three

*This opinion is contrary to that of some authorities. The tendons of the extensor communis digitorum do not run free over the two distal phalanges, but are bound down to them. Consequently it is maintained that, as they are not responsible for the extension of these phalanges, an action carried out by the interossei, it is unnecessary to prevent flexion beyond the first joint of the fingers. If, however, a piece of tape be stuck to the dorsum of the two terminal phalanges, leaving its free end on the back of the metacarpus, with the hand and fingers dorsiflexed, on flexion of the inter-phalangeal joints it will be noticed that the tape is pulled up the back of the hand at least half an inch. In other words, the extensor tendons are stretched at least this amount by allowing flexion of the two terminal phalanges.

exceptions: firstly, when a considerable amount of power of extension has already been regained—and in such a case a glove is often better; secondly, when extension of the fingers* has been recovered, but not that of the wrist; and lastly when, owing to median paralysis, it is undesirable to overstretch the flexors. In this latter case either a shortened splint may be used, or a long splint with only slight dorsiflexion. In mixed median and musculo-spiral injuries, even if the degree of paralysis of flexors and extensors is equal, it is not desirable to use quite a straight splint, for the mechanical advantage of the flexors over the extensors is so pronounced that the latter have to be given more than their share of assistance. As recovery progresses the splint should always be shortened to the level of the first interphalangeal joints.

There comes the question of the relative advantages of fixed and elastic splints. I believe that in the earlier stages of severe cases a rigid cock-up splint reaching to the finger-tips should always be preferred, as giving more absolute rest; while in the later stages, especially if the slightest efforts at recovery are taking place, the elastic glove or a spring cock-up splint will greatly encourage those efforts. In the early days of the war I was already using an elastic wrist-dorsiflexor of my own crude design, but I discarded this directly the Souttar glove was published. This glove, which can be used so long as the flexors are intact, is now so well known as hardly to need description, but, lest it should have escaped attention in any quarter, it is figured here (Fig. 1—frontispiece). In the original glove the elastic tendons, running in tunnels down the backs of the fingers and thumb, took their support from a band round the arm. This band was apt to slip and to cut the arm, and I have supplemented it by a moulded-leather cap† fixed on the shoulder by a diagonal chest-strap. The disadvantage of this arrangement is that, in certain positions of the arm, dorsiflexion of the hand is relaxed. I generally use now a moulded leather gauntlet on the forearm as a base of support for the rubber tendons (Fig. 46A).

So long as the flexors are undamaged this glove acts exceedingly well. The hand having been closed by voluntary effort, the elastic artificial tendons extend the fingers directly the flexors relax. Also, closure of the hand does not usually decrease—as one might, at first thought, fear—the dorsiflexion of the wrist, but increases it, for the flexion of the fingers stretches and pulls on the elastic tendons. Again, the normal position of maximum grip is with the wrist dorsiflexed, and any attempt to flex the wrist at once weakens the grip, so that patients involuntarily avoid wrist-flexion when possible. In many cases, however, there is a great tendency to wrist-flexion,

* That is, the first phalanges; the second and third are extended by the interossei.

† Should this cap show a tendency to slip it may be securely fixed by an attachment to the back braces.

either from old adhesions or from contracture; and in such cases a glove, while causing extension of the fingers, rather aids than otherwise the flexion of the wrist. Every time the fingers are used the wrist is flexed, and the glove is powerless to prevent this. In such cases it is necessary to apply, in addition to the glove, a short cock-up splint reaching to the metacarpal heads, and so not long enough to interfere with the finger-action.

It is generally advisable to replace the glove by a cock-up splint at night, as the tips of the fingers are otherwise apt to get sore from continued pressure; and it is advisable to have the glove made of as light and pliable a material as is consistent with reasonable durability, and also to have the palm well ventilated by large holes, as otherwise the glove becomes hot and sodden with perspiration; and, if possible, the material should be washable. I have generally used asbestol, but am still seeking the ideal material.

As regards the cock-up splint: there are several ingenious devices on the market, but I have found a simple sheet of aluminium with a separated thumb-piece, roughly moulded to fit the hand, and bent to a suitable angle, as comfortable as anything, and cheap, because indestructible (Fig. 18). In cutting out this splint due allowance should be made for the normal ulnar deviation of the hand.

In conjunction with the glove or splint the usual massage or electrical treatment should, of course, be carried out; though treatment is less essential with a glove than when a fixed splint is used, for with a glove there is constant interplay of muscles, and stagnation of vital circulation is avoided.

Whatever treatment is adopted it is essential that the masseur should be impressed with the fact that under no circumstances whatever must the extensors be allowed for one moment to be stretched while he is operating. The glove may be used either as a therapeutic measure or as a permanent substitute for the extensors in incurable cases.

*Lesions of more than One Nerve.*—The musculo-spiral nerve is frequently involved in conjunction with the median, the ulnar, or both. In most of such cases the glove is obviously unsuitable; but even here it is often possible to use some form of elastic tension, and thus enable the patient to use his hand. It cannot be too persistently reiterated that a hand that is *used*, provided that it is prevented from being mal-used, will recover much more quickly than one that is fixed in splints; and every attempt should be made, while correcting deformity and preventing the stretching of paralysed muscles, to leave the fingers free and useful.

An instance is shown in Figs. 19, 20, 21. In this case there was paralysis of extension of the middle and ring fingers, combined with ulnar-nerve paralysis. The deformity was the *main-en-griffe* of ulnar paralysis, and this had to be corrected before any form of extension could be used. A moulded aluminium splint was

accurately fitted to the palm in such a way that, by tightening the straps across the back of the hand, the metacarpo-phalangeal subluxations were reduced; this at once straightened out the semi-flexed fingers. The thumb was left free, as it was unaffected. Then a modified extension glove was fitted to the two middle fingers. The result was the immediate transformation of a completely useless hand into an eminently serviceable one, and the patient needed little encouragement to put it into constant use. Speedy improvement ensued, and the wounded man eventually left the hospital wearing no splint, and practically recovered.

Wounds of the other nerve trunks of the arm are scarcely suitable for treatment by artificial muscles; their treatment will be discussed in the next chapter, under the heading of "Rigid Supports."

## Facial Paralysis.

The usual advice in cases of facial paralysis is to treat the paralysed muscles by faradic current via the facial nerve, and by direct application of interrupted galvanic current to the muscles themselves. It is too frequently overlooked that these muscles are badly overstretched by the face being drawn to the opposite side. Under these circumstances it is not surprising that electrical treatment is often a failure, and, at the best, recovery is delayed.

A strip of adhesive plaster attached at one end to the corner of the mouth, and at the other to the temple, fully corrects the chief deformity, and permits the recuperation of the shortened muscles in cases in which the nerve is not utterly destroyed. To permit of a certain amount of elasticity to the face, a rubber band may be substituted for the plaster, stuck to broad plaster ends (Figs. 22, 23). It is necessary also to shift the site of the plaster slightly from day to day to prevent excoriation of the skin, or the skin may be rested from time to time by the use of a broad hook in the corner of the mouth, attached to an elastic band fixed behind the ear.

## Splints at Night.

Whatever elastic apparatus is worn in support of limb-muscles in the daytime, it must not be forgotten that it is often practically useless in bed at night; and, as in the analogous case of infantile paralysis, some form of light rigid support must be worn at night in all serious cases, to prevent the muscles from stretching. Neglect of this obvious precaution will, of course, tend to nullify all treatment during the day. Also, in cases taking thermal baths the patient must be warned always to supinate his forearm; if there is doubt about his carefulness a light splint should be bandaged on and worn during the bath (*cf.* p. 41).

# CHAPTER IV.

## RIGID SUPPORTS.

One of the surgical tragedies of the war is that, while the patient receives such skilled attention as has never before been dreamed of, he necessarily passes through many hands, so that no one man is responsible for the final results. From this cause those responsible for the earlier stages of treatment have little opportunity of seeing the case in its later stages, and consequently are apt to omit certain precautions of technique which they most certainly would have adopted had they had the end results passed habitually under their notice; on the other hand, those responsible for the final treatment can hardly visualize the difficulties besetting the path of their surgical forerunners, and are apt to wonder why certain obvious precautions—obvious, that is, to them as late-comers—were not taken in the earlier stages of the case.

Prevention is better than cure; and if these few pages serve, in ever so humble a degree, to draw attention to the frequency of preventible deformities—easily preventible deformities—they will not have been written in vain. For it is obvious that a splint that will correct and cure late deformity will, *a fortiori*, prevent it if applied directly after such operations as nerve-suture.

As this work makes no pretence of being a text-book of physical treatment, but is merely a series of notes of personal experience, no attempt will be made to describe or figure splints or supporting-apparatus already well known and described elsewhere.

The special splints here advocated are those that have been devised by the author to meet the exigencies of his own cases, and there are doubtless many others elsewhere evolved which serve the same purpose as well or better: in all cases their primary object has been the removal of deformity and the consequent relaxation of paralysed muscle. With few exceptions, as in the cock-up hand-splint, where the removal of deformity is exaggerated in the opposite direction, the one aim implies the other.

Hitherto we have considered paralysis and deformities that could conveniently be treated by artificial muscles. There are many others, however, which cannot so be treated, and for these some form of rigid apparatus has to be used. The most important and frequently met of these lesions are those affecting the shoulder-girdle, arm, and hand.

**Spinal Accessory Nerve.**

This supplies the sterno-mastoid and part of the trapezius. Wound of the nerve in the anterior triangle of the neck would paralyse the sterno-mastoid and to a large extent the trapezius. Probably because a wound in this situation is so likely to be fatal, I have as yet met with only a single case. In a lesion behind the sterno-mastoid the trapezius only is involved. Whether in the following case the third and fourth cervical nerves were also involved I am unable to state, as unfortunately the electrical reactions were never taken.

**Trapezius.**

Paralysis of this muscle, a very rare injury, results in a curious deformity, as shown in Figs. 24 and 25. The most striking features are a peculiar sharp mountain-top projection under the skin at the lower margin of the posterior triangle of the neck, caused by the superior angle of the rotated scapula; a retraction of the scapula from the middle line of the back; a condition of slightly winged scapula, a projection confined to its upper half, and one which is not increased by a forward thrust of the arm, therein contrasting sharply with serratus magnus paralysis (Figs. 27 and 28); and, above all, a peculiar squareness of the shoulder, caused by the horizontal line of the clavicle showing up without its background of trapezius, where, as posterior margin of the posterior triangle of the neck, it has atrophied away. The rhomboideus minor shows like a cord under the skin.

*Treatment.*—The deformity is one not easy to correct, and, unless it is corrected, the overstretched muscles cannot be expected to recover. An ordinary deltoid abduction splint, however, with a slight forward and upward twist, very nearly holds the scapula in position (Fig. 26). It has, of course, to be worn persistently, and need not be disturbed while giving electrical treatment.

**Long Thoracic Nerve—Serratus Magnus.**

Paralysis of this muscle, while frequent enough amongst soldiers as the result of injury from bruises of the chest-wall involving the long thoracic nerve, or from cerebro-spinal meningitis, would appear to be rare as the result of actual wound. The familiar winged deformity, increased by forward or upward thrust of the arm, is well shown in Figs. 27 and 28. It was corrected here by a plaster-of-Paris cape covering both upper arms, but permitting a restricted use of both hands.

**Circumflex Nerve.**

Paralysis of this nerve may occur from wound of the posterior cord of the brachial plexus, from wound of the nerve itself, from

blows upon the shoulder, or, most commonly perhaps of all, in the form of deltoid atrophy from injuries of the shoulder-joint, to which it sends an articular filament.

*Paralysis* affects the deltoid and teres minor, of which the former muscle only is of importance from an orthopædic point of view.

*Anæsthesia.*—Over the lower two-thirds of the deltoid area.

*Deltoid.*—Active treatment must be preceded by supporting the arm and forearm in an abduction splint. This splint as usually made is faulty, in that the trunk limb of the splint is too short. If this is lengthened so as to take its leverage from an expansion over the pelvis instead of from the lower ribs, not only is a broader and firmer base of support given, but the long supporting-arm of the lever acts at a greater mechanical advantage (Fig. 26). If necessary this splint may be hinged at the axilla and its angle of inclination controlled by a screw.

## Ulnar Nerve.

Gunshot wound of the arm involving the ulnar nerve is one of the commonest of all wounds calling for physical treatment—indeed, in my experience, ulnar-nerve injuries distinctly outnumber even those of the musculo-spiral. Very frequently the injury is complicated by simultaneous wound of the musculo-spiral or median nerves, or both; and the deformity in unsplinted cases is then so great that in no other wound-paralysis is it more necessary, before starting electrical and massage treatment, to apply some form of mechanical support that will correct it and relax the overstretched muscles. Even in uncomplicated ulnar-nerve paralysis this rule generally holds good. To correct all the deformities, with the minimum discomfort to the patient, requires a close attention to the distribution of the nerve and the anatomical structures involved.

Figs. 29 and 32 show the typical deformity* of ulnar paralysis, the familiar *main-en-griffe*. The major part of the deformity is caused by the uncontrolled action of healthy muscles when their opposing muscles are paralysed; and as a result of the deformity the tendons of some healthy muscles are overstretched, thus superadding the weakness of overstretched muscles on the uselessness of paralysed ones. In addition, unnaturally exposed articular surfaces are liable to constant injury, and their surfaces tend to alter in shape. Apart, therefore, from any æsthetic reasons or of consideration of the actually paralysed muscles, it is necessary, as a preliminary to other treatment, to correct the deformities. Let us consider these in detail.

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* Complete nerve-division is characterized by hypotonia, incomplete division and nerve-irritation by fibrous muscular contraction and consequent deformity. As cases of complete division are little amenable to physical treatment it will be understood that incomplete division is generally implied in the description of clinical conditions here.

(*a.*) There is hyperextension, amounting sometimes almost to dislocation, of the first phalanges of the fingers on the metacarpal heads, with partial flexion of the second and third phalanges. The action of the interossei is to flex the first phalanges and extend the second and third; and, as all the interossei are supplied by the ulnar, generally all four fingers are affected. As a rule, however, the fore and middle fingers are much less affected than the little and ring fingers, and sometimes they show scarcely any deformity at all (Fig. 29). This is due, I take it, to the two outer lumbricals, whose action is identical with that of the interossei, being supplied by the median nerve. The check action of these muscles in a large degree prevents the full development of the deformity. Finally the little finger is especially affected, as it feels the loss of the abductor minimi digiti and of the flexor brevis minimi digiti, which act like interossei.

As a consequence of the dorsiflexion of the metacarpo-phalangeal joints the long flexor tendons are overstretched, and the fingers are further flexed to accommodate them; also some weakening of the long flexors is apt to result. Further to accommodate the long flexors there is often a pronounced flexion of the wrist, which, due originally to the habitual assumption of the position of greatest ease, may become permanent.

(*b.*) Radial deviation of the hand (Fig. 30). Normally there is a distinct ulnar deviation of the long axis of the hand on the forearm; in ulnar paralysis this is usually diminished, lost, or replaced by a radial deviation, and the grip of the hand thereby greatly weakened. In wounds at or above the elbow this deviation is due to paralysis of the flexor carpi ulnaris and half of the flexor profundus digitorum, allowing uncorrected action of the muscles on the radial side of the wrist. The condition is apt to be much accentuated by the common practice of carrying the unsplinted forearm and hand in a sling, when the principal strain falls on the ulnar border of the hand. It is corrected by cutting the ulnar splint (Fig. 33) with an ulnar deviation.

In recovering cases, when the *main-en-griffe* has been already corrected, and radial deviation alone remains, a very simple apparatus will serve. Thus Fig. 30 shows a recovered paralysis, with a fairly firm radial deviation, in which a moulded poroplastic splint (Fig. 31), made with a hole for the thumb, permanently reduced the deformity after being worn for two weeks. This small splint does not interfere seriously with the use of the hand in such simple but important matters as holding a knife and fork.

(*c.*) There is generally obstinate contracture-flexion* of the first nterphalangeal joints of the little and ring fingers, especially of the jittle finger, and considerable and prolonged force is often needed to lecure extension. In long-standing cases the contracted condition of she long flexor muscles constitutes a serious obstacle to recovery,

* *Cf.* footnote, p. 52.

and should, of course, be met by early preventive measures rather than by late remedial ones.

The flexion appears to be caused not only by action of the flexor sublimis, unopposed by the interossei and lumbricales, but possibly by a secondary contracture of the ulnar half of the flexor profundus digitorum.

(*d.*) Flexion of the thumb at the interphalangeal joint (Fig. 32). This condition is not invariable, but is of extremely frequent occurrence, and appears to be overlooked by the text-books, or at any rate by those to which I have had access.* The condition is not due to a contracture, but is paralytic and, so to speak, atonic, and, while easily reduced, is very persistent. I am indebted to Professor Gowland, of the Otago University, for the following explanation of the deformity: The abductor pollicis, the flexor brevis pollicis, the deep head of the flexor brevis pollicis (first palmar interosseous), and the adductor pollicis send slips to the tendon of the extensor longus pollicis, and the adductor pollicis and first palmar interosseous are supplied by the ulnar nerve. Apart from any other action they may have, they all flex the first phalanx by their insertion into its base, and extend the second phalanx by their insertion into the tendon of the extensor longus pollicis. When the two ulnar muscles are paralysed the other two may or may not be sufficient to carry on their action, and in the latter case paralytic flexion results from the uncorrected action of the flexor longus pollicis and extensor brevis pollicis.

(*e.*) There is wasting of the interossei, especially noticeable in the pronounced hollow between the metacarpals of the thumb and forefinger, on the back of the hand. There is wasting of the thenar and hypothenar eminences, and, in high wounds, of the ulnar muscles of the forearm.

In addition to the deformities, the following symptoms will be noted: As a result of paralysis of the interossei the fingers can neither be separated nor approximated, though some considerable degree of abduction of the forefinger may be possible through the action of the extensor communis digitorum, and may thereby raise false hopes of a recovering ulnar paralysis.

In regard to the thumb, some caution in investigation is necessary. At first sight adduction seems possible, but a closer examination will show that this adduction is not performed by the ulnar adductors, for the thumb is adducted *with the terminal phalanx bent.* A rough test is to pull on a piece of paper held in position by the adducted thumb: in ulnar paralysis it cannot be retained while the thumb is held straight, and is only grasped by the terminal phalanx.

(*f.*) There is usually limited power of flexion of the ring and little fingers.

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* While this is in the press I find it described by Tinel, quoting Jeanne.

(*g*.) *Anæsthesia.*—The area of anæsthesia varies less than in the case of the median and musculo-spiral nerves, though it very occasionally does not include half the ring-finger (Fig. 32). At the wrist it merges into the territory of the internal cutaneous (Fig. 29). As a rule, the area of protopathic closely follows* that of epicritic sensation (Fig. 32). In recovering cases the ulnar border of the hand and the proximal phalanx of the ring-finger and middle finger (dorsal ulnar edge) are the first areas to regain sensation, then the rest of the ring-finger, and last of all the distal phalanges† of the little finger, the latter an event often delayed for months.

The importance of this observation lies in the fact that in recovering cases an abnormal nerve-distribution may be assumed, or even anæsthesia overlooked altogether.

(*h*.) Trophic changes, tropho-neuroses (see p. 17).

*Treatment.*—It is assumed that probable continuity of the nerve has been deduced by the usual tests, or that nerve-suture has already been performed. Before starting electrical treatment it is necessary to prevent or correct the deformities already discussed in paragraphs (*a*) to (*d*), and to keep them corrected day and night by means of a suitable splint. There are doubtless many splints in use which fulfil this purpose. Those shown here (Fig. 33 *et seq.*) are the outcome of many experiments, and I have found them very satisfactory. In unmixed ulnar cases, without thumb-flexion, the splint is very simple; in thumb cases, or those complicated by injury of other nerves, it necessarily requires considerable modification.

A rough tracing of the extended hand is taken on paper; and from this is cut, from a sheet of aluminium, a slightly larger splint (it is made larger to allow for a comfortable dishing of the surface to fit the contour of the palm). The splint reaches about 4 in. up the flexor surface of the forearm; has a straight piece to extend the little and ring fingers; is then cut away in a concave sweep to the head of the metacarpal bone of the forefinger, and thence sweeps back in a bay to the wrist, leaving the thenar eminence, the thumb, and the first two fingers free for use. From the wrist to the metacarpal heads there is slight dorsiflexion; opposite the metacarpo-phalangeal joints the splint is more or less sharply flexed, and it is essential that this bend in the splint should follow the true line of these joints—that is, should be oblique, and not at right angles to the long axis of the splint: and, indeed, the whole splint must be cut with a normal ulnar deviation. This splint, with its double inclined plane, flexes the metacarpo-phalangeal joints and extends the inter-phalangeal—that is, it assumes the function of the paralysed interossei; in so doing, the subluxation of the bases of the first phalanges is generally reduced. In severe cases it is sometimes necessary to

* Often, however, there is loss of epicritic sensation over the dorsum of the first phalenx of the ring-finger and half of that of the middle finger.

† The last phalanges of the little finger are supplied by the dorsal collateral nerves; in the ring-finger the palmar collateral supplies both the palmar and dorsal surfaces of the last two phalanges.

supplement the action of the double inclined plane by that of a semicircular convexity of the splint along the line of the metacarpal heads, thus pushing them into place. Should there be any difficulty in getting this ridge made, a split cork, fastened with glue or adhesive plaster, serves admirably. This splint corrects the deformity, is clean, light, and comfortable, and allows the full use of the thumb and first two fingers, thus preventing stagnation of circulation of the hand. In cases in which there is severe contraction of the little finger, it is usually necessary to supplement this splint by a narrow strip of padded wood or metal along the back of the finger, and held in place by a leather strap or by the splints shown in Figs. 35, 36, and 37. In " thumb cases " the same splint is used with the addition of a thumb-piece (Fig. 34).

In combined musculo-spiral and ulnar paralysis we have to correct both the wrist-drop and the *main-en-griffe;* it is therefore absolutely necessary to use a cock-up splint, and this necessarily increases the tendency to subluxation at the metacarpo-phalangeal joints; also the thumb must be kept extended and abducted. A modified form of the ulnar splint meets the difficulty. A tracing of the whole hand is taken with the thumb abducted. The splint is then cut in one piece from a sheet of aluminium, care being taken to give it ulnar deviation and to make the hand-piece $\frac{3}{4}$ in. too long, to allow a raised ridge across the metacarpo-phalangeal joints. The splint is then dorsiflexed from the wrist, and the thumb-piece given a twist on its long axis; its raised inner edge then effectually prevents adduction of the thumb. Care must be taken that this thumb-piece is flexed, rather than dorsiflexed. A couple of straps riveted to the splint keep the whole in position (Fig. 39).

Combined median and ulnar paralysis would appear to be exceedingly rare, if I can judge by my own experience. The median is almost entirely a " flexor nerve," and the commonest deformity met with in partially paralysed flexor muscles is contracture. In the few cases that I have met with, flexor contracture of the wrist has been the main added trouble, and this is met by the combined musculo-spiral and ulnar splint last described. It is curious to note that in median paralysis the forefinger remains paralysed long after the other fingers have recovered.*

Combined ulnar, median, and musculo-spiral paralysis is usually due to injuries high up in the brachial plexus. The hand-deformity is met by the same splint as already figured for mixed ulnar and musculo-spiral cases.

## Slings.

There is no need to discuss the slings commonly in use, but the two shown here will be found useful in special cases (Figs. 40 and 41; compare also Fig. 3).

* The muscular slip of the long flexor to the forefinger receives no accessory fibres from the ulnar.

# CHAPTER V.

## ADHESIONS AND CONTRACTURES.

Very serious deformity and loss of function occur from adhesions, contractures, and allied conditions, the secondary results of nerve-lesions, especially nerve-irritation. Some of these conditions, and their appropriate treatment, have already been considered, but it will be convenient to devote a short chapter to the consideration of special methods of reduction. The chief methods at our disposal are—

(1.) Forcible reduction under an anæsthetic :
(2.) Gradual reduction by means of splints worked by a screw thread :
(3.) Gradual reduction by the slow steady tension of rubber bands :
(4.) Mechano-therapy, utilizing pendulum motion or weights and pulleys :
(5.) Plaster-of-Paris wedge :
(6.) Persistent use of the part by voluntary or involuntary action :
(7.) Massage and manual passive movement :
(8.) Baths :
(9.) Ionization :
(10.) Suggestion, in hysterical contracture.

1. Forcible reduction under an anæsthetic is perhaps most frequently employed at the knee-joint. It is needless to point out here the many obvious dangers of this procedure, which should only be employed in selected cases. One has to bear in mind the possible presence of foreign bodies, of callus, and of alterations of alignment of fractured bones making reduction of the deformity impossible. This latter cause is especially to be looked for in the elbow-joint. It is always advisable, therefore, to get a good X-ray picture of the joint and its neighbourhood before attempting forcible extension, for it is generally extension that is required. The danger of lighting up a slumbering sepsis is ever present, and that of rupturing sutured nerves and shortened arteries, bound down perhaps by adhesions.* A very troublesome condition is shown in Fig. 42, which represents a contracted knee after sciatic suture. On account of loss of nerve-tissue, suture could only be performed with the knee kept flexed. The limb was allowed to remain too long in this position, and fibrous ankylosis resulted, with a nerve showing only the feeblest possible signs of recovery. Attempts at extension by a weight and pulley only caused incipient gangrene of the toes. Eventually the knee was

* As far as possible the breaking-down should be a single strong movement, "seesawing" should be avoided.

partially extended under an anæsthetic, and extension applied by rubber bands (method 3). A second anæsthetic and prolonged elastic treatment, combined with persistent massage and electricity, eventually resulted in recovery with only a slight flexion.

2. There are several efficient splints worked on the screw principle, but as a rule they interfere with clothing,* and so with walking about, and therefore with recovery. Fig. 56 shows a locally made knee-splint which can be worn under the trousers. It can be extended or, of course, flexed, by inserting a wire nail as a lever into the lateral hole in the female screw.

3. Elastic tension lends itself readily to most forms of contracted joints and contracted muscle. We have already noted its use in the knee-joint and in the hand (Fig. 45). Its application is only limited by the ingenuity of the surgeon. Thus, for extension of the elbow-joint, a moulded splint firmly fixed to the back of the upper arm projects as far as the wrist at an acute angle with the forearm. A protecting leather gauntlet encircles the lower forearm, and a rubber band passes over this and binds it to the splint. To flex the fingers a glove and gauntlet is worn, with stout rubber bands sewn to the backs of the fingers from root to tips and then drawn down to meet the gauntlet in the palm. In milder cases a simple elastic band drawn round the partially closed fist will suffice.

4. As already indicated, there are considerable risks attached to the use of machines, especially if *passive* movement is attempted. Only old-standing cases, in which the danger of relighting up sepsis is at a minimum, should be treated by this method (Figs. 58, 59).

5. This is a simple and interesting method, which I have adopted with grateful acknowledgments to Shepherd's Bush, and is more particularly applicable to the hand. Figs. 52 and 53 show a good example. The hand is greased, the fingers pulled out as much as possible, while thick plaster-of-Paris is poured in. Until this has set, the fingers are retained in position by the operator. The mould is then removed, allowed to harden, and washed with soapy water. It is then reinserted and worn for a day or two, when the fingers will be found to have " given " a little. Fresh layers of plaster are added, or wedges of felt or other material are inserted between the mould and the fingers, and after a time a fresh mould is made. Finally the fingers are straightened on a metal splint (Fig. 35).

6. Use of the part in ordinary everyday occupation will often do wonders, but it must be remembered that the flexor muscles always have a mechanical advantage over the extensors, and that use will make a semi-flexed knee, for instance, more flexed. Unrestrained ordinary use, therefore, is generally only indicated when additional *flexion* is required.

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* For reasons given in the preface, Turner's and other well-known splints are not described.

7. This method requires no comment except the remark that its effect is greatly enhanced by the use of method 8.

8. Baths: Mineral-water hot baths, by increasing the local circulation and by softening the tissues, greatly aid the masseur. The same may be said of local hot-air baths, at from 250° F. to 400° F., as a measure preliminary to treatment.

9. Ionization with chlorine or iodine ions hastens the absorption of, or softens, fibrous tissue. Its use is limited in the large joints by the low rate of penetration of the ions—only a few millimetres at a sitting. The cathode, of course, is used locally, and the utmost bearable milliampèrage, the current being slowly and smoothly increased and turned off. The very greatest care in attention to details must be taken, or very troublesome burns are apt to occur.

10. Suggestion: Contracture of hysterical origin may be overcome by suggestion, with or without hypnosis. Of the former method I have no experience; the latter, of course, is in constant use. A modified form of suggestion is to move the part freely under a general anæsthetic, and to impress on the patient, both as he goes under and as he begins to recover consciousness, the success of the "operation." This treatment applies equally to hysterical paralysis.

# CHAPTER VI.

## CONSTRICTION HYPERÆMIA.

### Bier's Bandage.

This will be found a most useful adjunct in the treatment of atrophic conditions due to nerve-wounds. That it has not been used more widely is due, I think, to a want of consideration of the principles underlying its use, and therefore to a failure to employ the bandage to its fullest advantage. As usually applied it consists of an elastic band fastened round proximally to the part affected, and with just sufficient tightness to stop the venous circulation more or less entirely, but not to interfere with the arterial supply. The bandage is left on, with intermissions, for a large portion of the twenty-four hours. For reasons that will now be given I have employed with success a somewhat different method. In the first place, in many of these nerve cases the border-line of gangrene is never far off, and long-continued constriction would be very dangerous; in the second, alternative hyperæmia gives better results.

The plan I adopt is this: The bandage is applied in the usual way, and the affected part made blue and swollen—that is, gorged with venous blood—for, say, ten minutes; the bandage is then removed and the part vigorously rubbed until it is pink—that is, until an arterial hyperæmia has been substituted for a venous engorgement. It will be noted that the former (arterial) is an *active* hyperæmia, the latter a *passive*; and the effects on the blood-content differ as markedly as the effects on the blood-circulation. Active hyperæmia causes a local rise in the red-blood count to a very considerable degree, and a slight leucocytosis, together with an increased hæmoglobin percentage and an increased blood specific gravity. Passive hyperæmia causes a great leucocytosis and a diminished red-corpuscle count. This phenomenon was first pointed out by Winternitz; and in a series of experiments that I carried out some ten years ago in connection with an investigation into the action of mineral-water baths I was able fully to confirm his observations on the blood-count.

The effect, then, of alternating active and passive hyperæmia is not only to cause an alternating arterial and venous hyperæmia, but to cause a local increase in the supply of both red and white corpuscles.

In mild cases the period of constriction may be increased materially, but every case requires watching, and an intelligent patient can soon be taught to do this for himself.

The following two cases well represent two types of trophic disturbance: the pseudo-hypertrophic (Fig. 54) and the atrophic (Fig. 55). Both respond to hyperæmic treatment.

While on this subject it may be remarked that this same hyperæmia is an important factor in the rationale of treatment by hot baths, more especially at Rotorua, where, by employing different classes of water, an active or passive hyperæmia can be obtained as desired.

FIG. 2.—"Raindrop hand."

FIGURE 5.

The light area, about 6 in. in length, opposite the middle of the thigh, is strong elastic webbing; the upper part is plain webbing; the lower portion consists of two leather straps, adjustable as to length by means of buckles. Should the long strap show a tendency to slip off the front of the knee a knee-cap has to be added, with a small loop to hold the long strap in place. The whole apparatus costs only 10s. 6d.

FIG. 3.—Elastic sling for stiff elbow.

FIG. 4.—Artificial biceps.

FIG. 5.—Long quadriceps strap.

FIGURE 6.

Private E.—Gunshot wound of both thighs at Somme. Bullet traversed both thighs behind the femurs at about 2 in. below the level of the trochanters, from right to left, injuring both sciatic nerves. Date of wound, 1/10/16. Admitted to Rotorua Hospital, 1/9/17.

*Condition on Admission.*—Foot-drop both sides; marked peroneal paralysis left side; incomplete R.D.; anæsthesia over lower part of left fibula, and to some extent of right; brisk knee-jerks; right exaggerated pseudo-plantar* reflex; walks with one stick.

*Treatment.*—Double long elastic strap; farado massage; interrupted galvanism.

*Result.*—Walks without a stick.

* That is, on trying for the plantar reflex the whole leg is drawn up in a clonic convulsion, but the toes appear to be unmoved—a frequent phenomenon in sciatic-nerve injuries.

Fig. 6.— Double long quadriceps strap.

Fig. 7.—Long elastic strap, with knee-cap.

FIGURE 8.

Rifleman G.—Gunshot wound of head at Somme; complete right hemiplegia for seven weeks. Date of wound, 5/10/16. Admitted to Rotorua Hospital, 1/8/17.

*Condition on Admission.*—Large depressed fracture over left of sagittal suture; hemiplegia recovered, except for weakness of extensors of right leg and of peronei; knee hyper-extended.

*Treatment.*—Long elastic strap, with check hinge to knee; farado massage.

*Result.*—Discharged from hospital, 26/11/17, walking with one stick.

Fig 8.—Long elastic strap, with check extension hinge for the knee-joint.

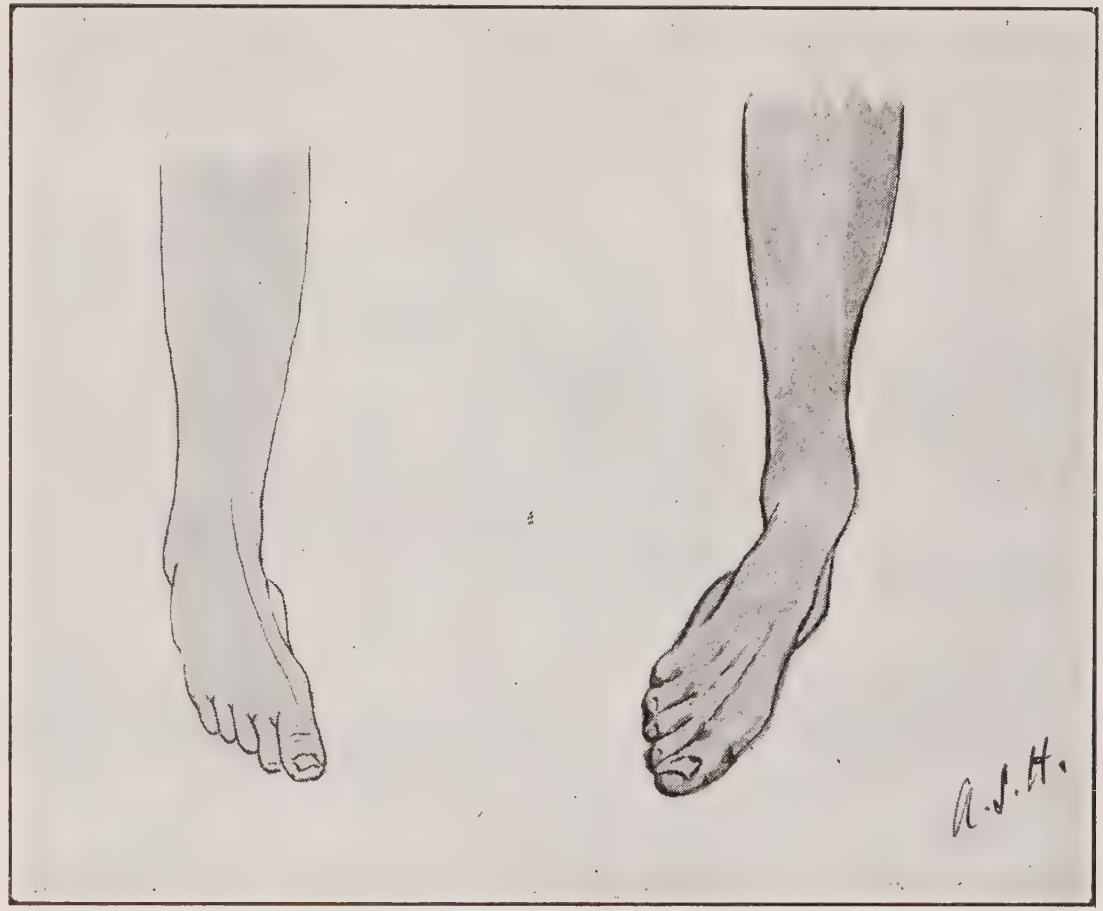


Fig. 9.—Voluntary extension of foot in paralysis of peronei.

Fig. 9a.—Voluntary extension of foot in paralysis of the tibialis posticus.

Fig. 10.—Paralysis of peroneus longus and brevis, and quadriceps paresis. (Note the helpless attitude.)

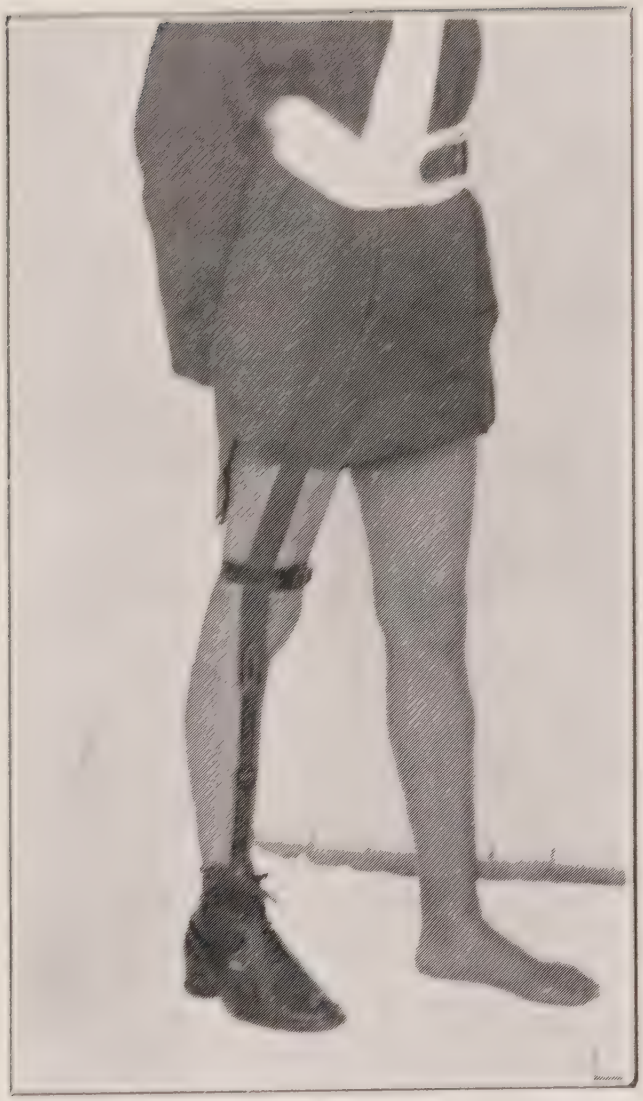


FIG. 11.—The same patient as in Fig. 10 fitted with a long extension strap with proximal attachment only. (See the next article.)

FIGURE 12.

Private F.—Gunshot wound of the left fibula; 5 in. of the bone removed by operation; numerous incisions in calf for sepsis; secondary hæmorrhage; ligature of popliteal artery. Date of wound, 21/8/15. Admitted to Rotorua Hospital, 10/9/16.

*Condition on Admission.*—Adhesions about calf-muscles prevent dorsi-flexion of foot, so that patient is unable to put the heel to the ground; inversion of foot from failure of peronei.

*Treatment.*—Massage; calliper with external elastic strap. This remedied the deformity, but the apparatus is only recommended in special cases such as this where the fibula also needs support. In ordinary cases the short elastic strap should be replaced by a long one taken from the shoulders.

*Result.*—Walked fairly well, but further surgical treatment of the bone was necessary.

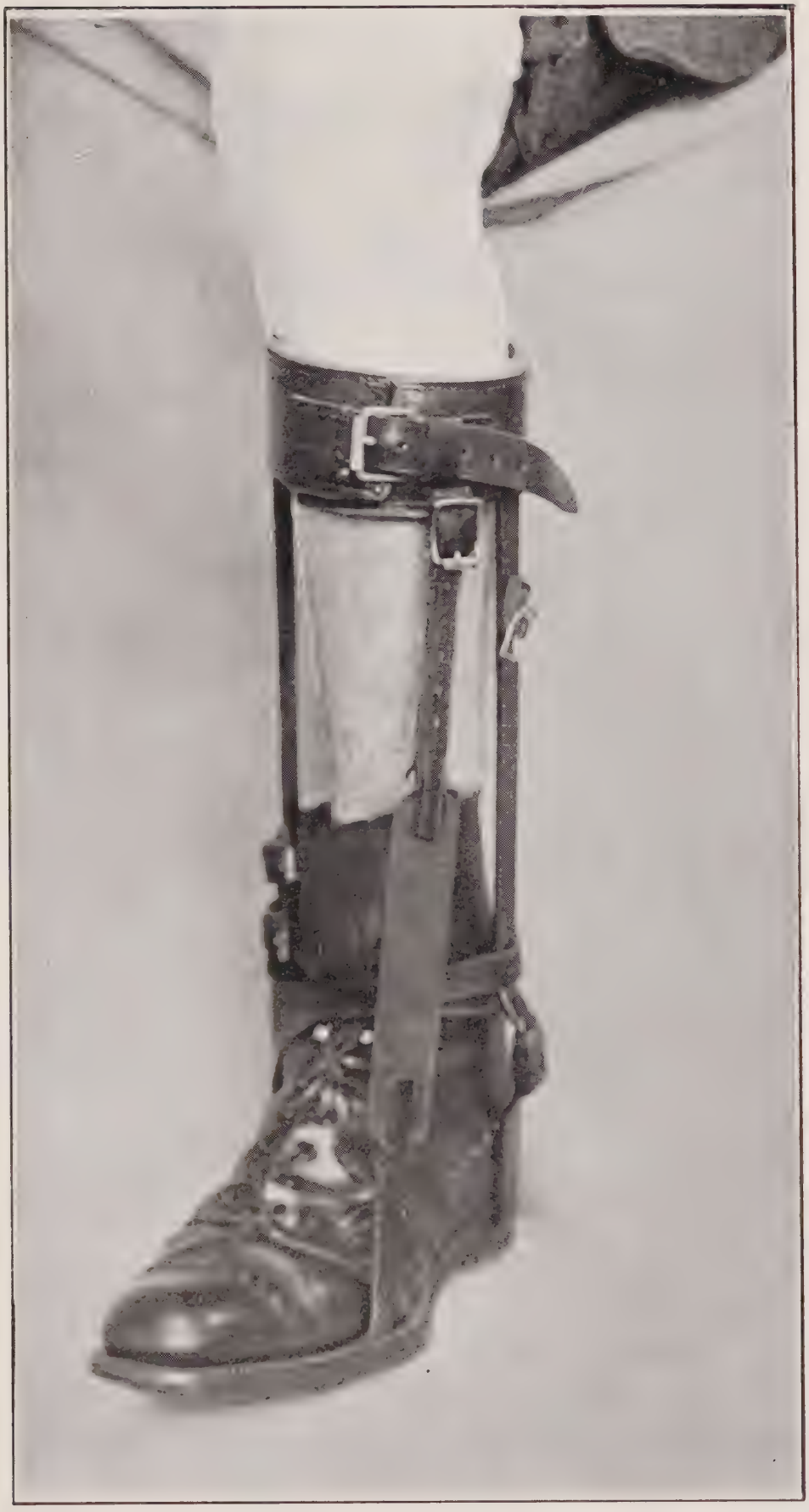


FIG. 12.—Short calliper, with short elastic-strap attachment for paralysis of peroneal muscles.

FIGURE 13.

Private C.—Bullet wound of lower third of left tibia, carrying away a large portion of the inner face of the bone and leaving a gap of 2 in. Date of wound, 7/8/15. Admitted to Rotorua Hospital, 3/11/16.

*Condition on Admission.*—Large "bite" out of the inner side of the left tibia; tendon of extensor proprius hallucis destroyed, causing great-toe drop; no anæsthesia; walks with two crutches.

*Treatment.*—Calliper splint, with elastic tendon on great-toe side; active movement of ankle-joint on machine; farado massage of extensors.

*Result.*—Patient at once walked with one stick, but after a short trial, as the foot felt heavy, a long elastic strap from the shoulders was substituted for the short elastic strap from the calliper. Patient then walked almost naturally, and was discharged from hospital wearing the apparatus.

FIG. 13.—Gunshot wound of tibia destroying tendon of extensor proprius hallucis.

FIG. 14.—The same case as in Fig. 13, fitted with a short calliper and short elastic-strap attachment (not recommended)

FIG. 15.—Bed-boot.

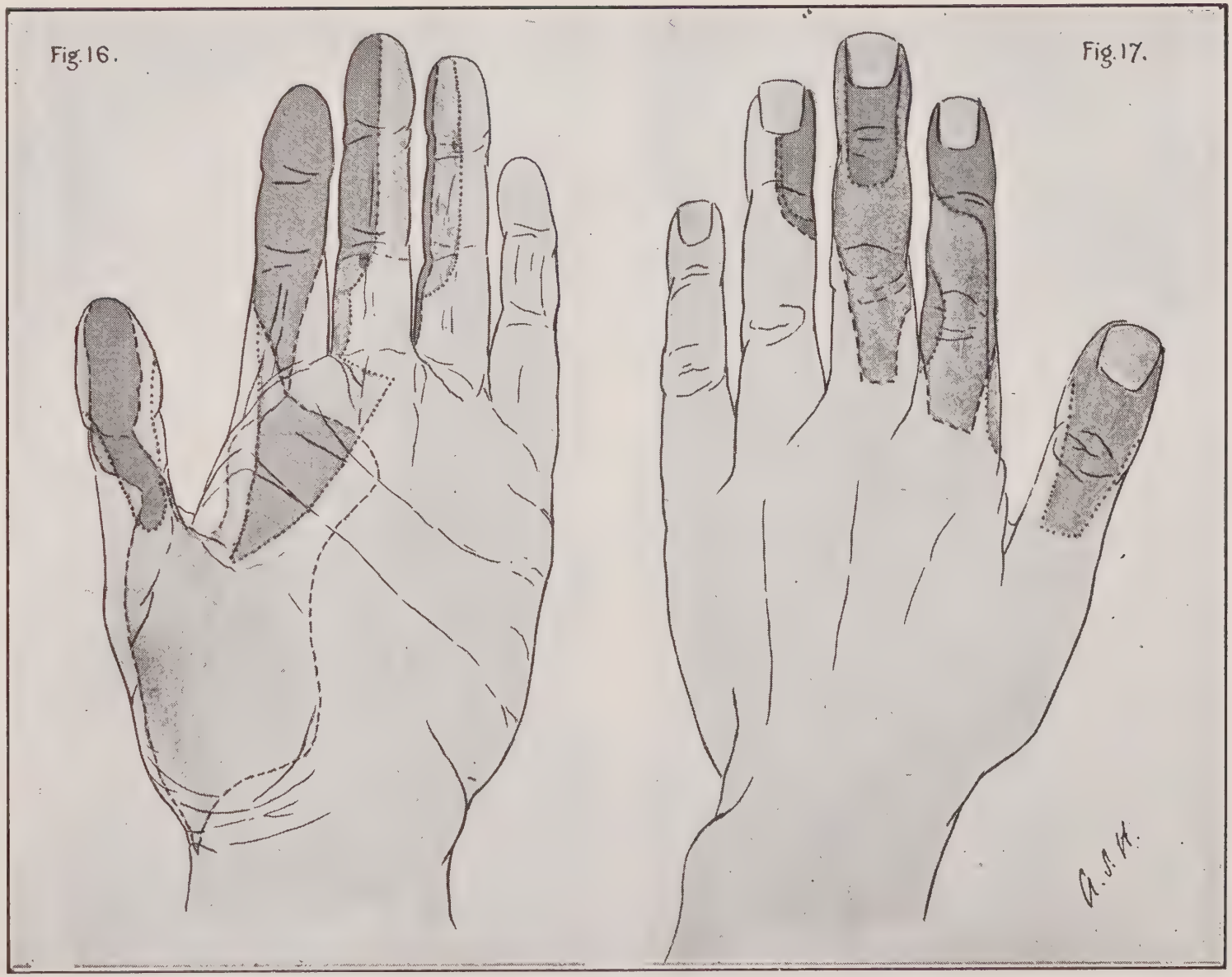



Fig. 16.— Median-nerve anæsthesia.
(The shaded areas show the zone of loss of protopathic sensation—the darker where, in two cases, the areas overlapped.)

Fig. 17.—Median-nerve anæsthesia: Back of hand for the same two cases as in Fig. 16.

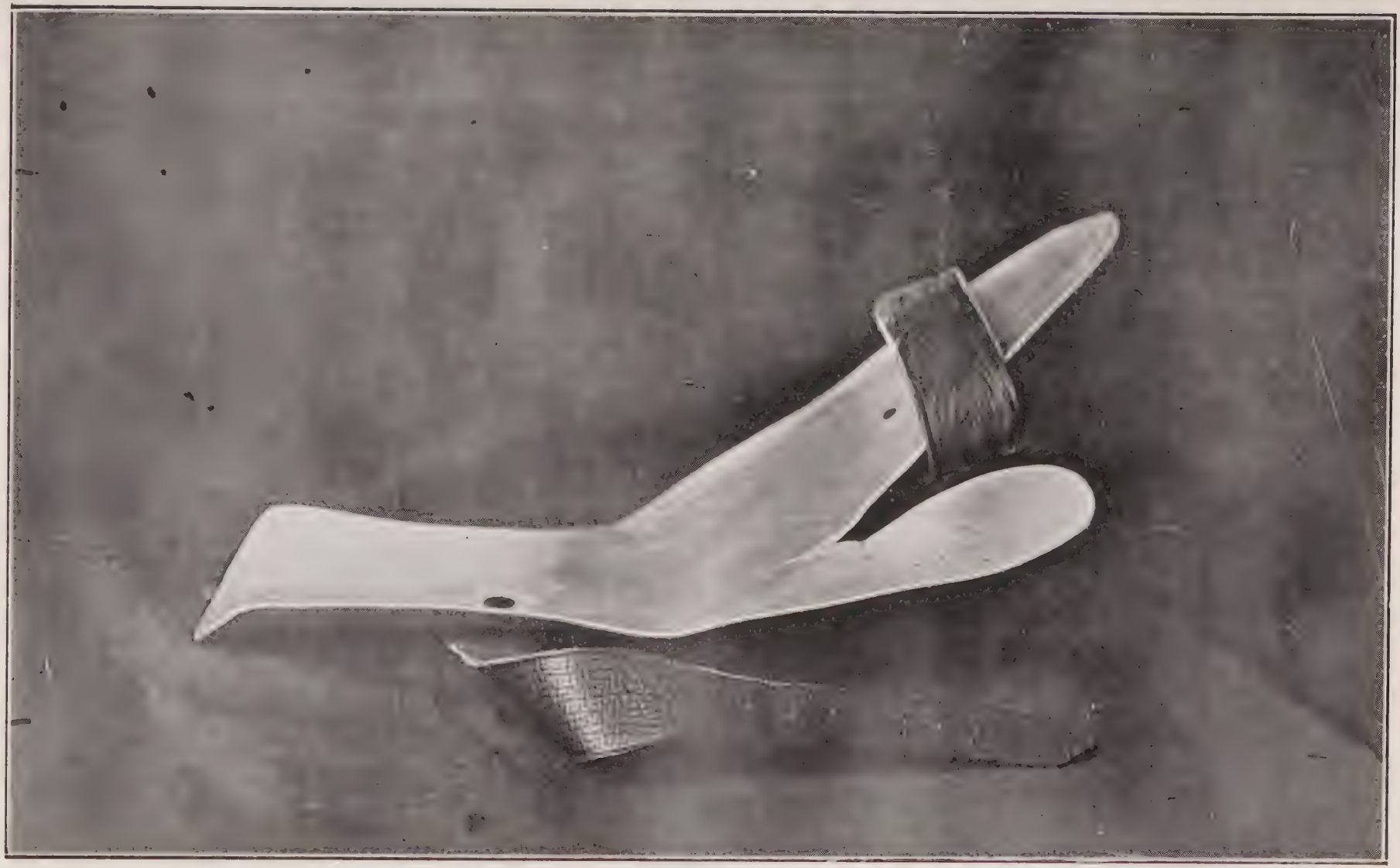


Fig. 18.—Cock-up aluminium splint for drop-wrist.

(Note that the hand-piece must be cut with the normal ulnar deviation, and that the abducted thumb-piece must be slightly flexed, or at any rate not dorsiflexed.)

FIGURES 19, 20, 21.

Corporal S.—Bullet wound at Gallipoli of left arm above the elbow; entrance externally, exit just above internal condyle; median and ulnar nerves sutured. Date of wound, 21/8/15. Admitted to Rotorua Hospital, 7/9/16; discharged, 5/2/17.

*Condition on Admission.*—Complete ulnar-nerve anæsthesia, but sensation in little finger on pressing on nerve in upper part of wound; incomplete R.D.; paralysis of interossei; median-nerve area, sensation normal; loss of power of extension in middle and ring fingers; ring finger kept flexed.

*Treatment.*—Farado-massage and special apparatus shown in Figs. 20 and 21.

*Progress.*—Ulnar sensation gradually returned, beginning with the ulnar side of the ring-finger; extensor power gradually returned to the two middle fingers, but for a long time was "delayed" in action and incomplete in ring-finger; very slowly the interossei recovered. Wearing the apparatus, a useful hand was obtained from the first.

*Result.*—Patient left the hospital with a good useful hand after the apparatus was discarded. Recovery was not quite complete, but the condition was steadily improving.

*Diagnosis.*—Division of median and ulnar, and concussion of musculo-spiral nerves.

Fig. 19.—Ulnar, median, and musculo-spiral paralysis.

Fig. 20.—Combined rigid and elastic apparatus for correcting the deformity in case Fig. 19, while retaining a useful mobile hand.

FIG. 21.—Palmar view of splint shown in Fig. 20.

Fig 22.—Right facial paralysis.

Fig. 23.—Case in Fig. 22: Paralysis corrected by elastic support of strapping and rubber.

FIGURES 24, 25, 26.

Private H.—Fell down a companion-way on hospital ship "Marama," damaging right scapular region; was unable to use the arm properly afterwards. Date of injury, April, 1916. Admitted to Rotorua Hospital, 10/10/17.

*Condition on Admission.*—Wasting of muscles about the right scapular region; scapula winged at its upper extremity, and the bone tilted forwards and outwards so that the superior angle forms a sharp promontory under the skin; the clavicular line forms a sharp horizontal ridge owing to the absence of the edge of the trapezius between the shoulder and neck; movements of the arm at the shoulder-joint fairly good; upward and forward thrusting scarcely increase the deformity, but the weight of the arm at rest dislocates the scapula.

*Treatment.*—Abduction splint,* farado massage, and interrupted galvanism.

* In a second similar case, with simultaneous paralysis of other scapular muscles, the deformity was less, and could not be corrected by this splint. In deltoid cases the right-angled piece may be hinged at the axilla, and the angle increased or diminished by means of a screw.

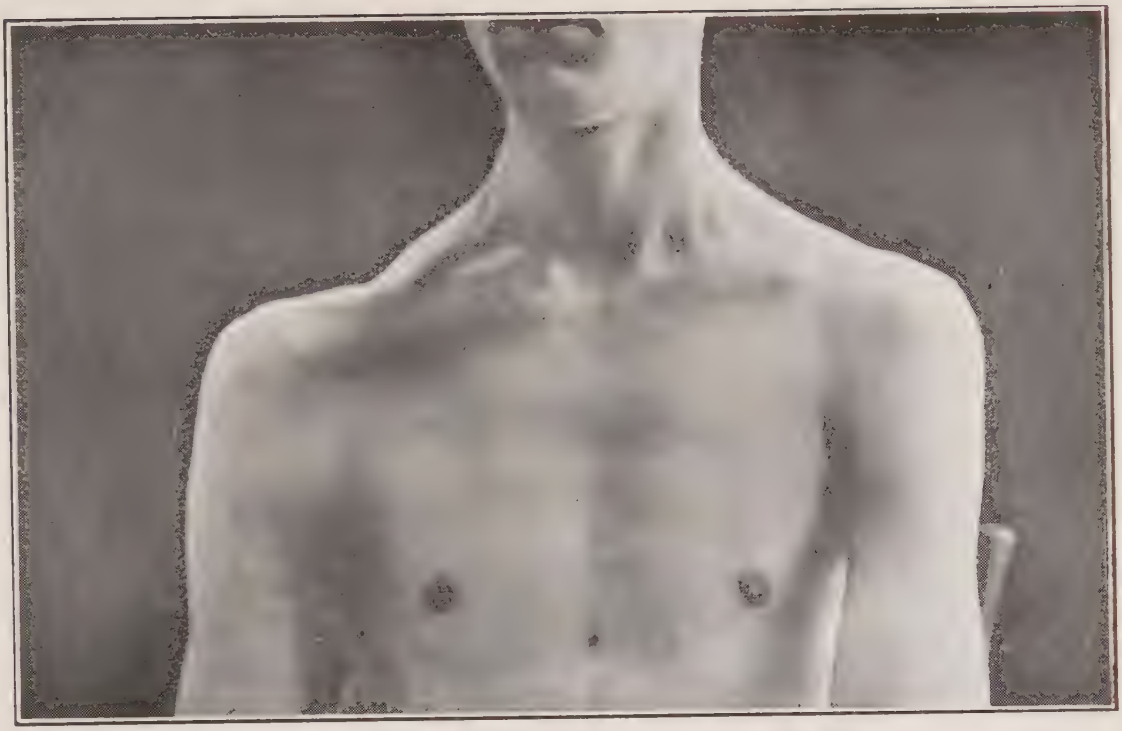


FIG. 24.—Paralysis of right trapezius.

FIG. 25.—Paralysis of trapezius, back view. (Arrow points to the superior angle of the scapula.)

FIG. 26. — Paralysis of trapezius: abduction arm-splint applied.

FIG. 27.—Paralysis of serratus magnus on both sides. Deformity increased by forward thrust of arms.

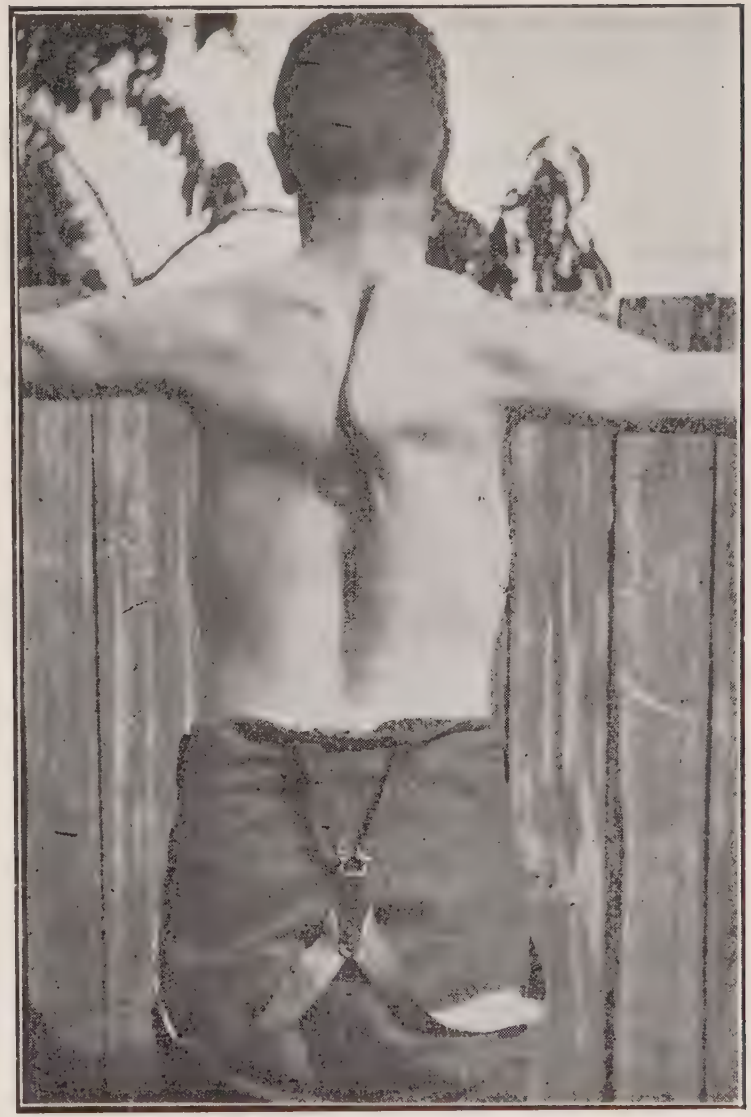


FIG. 28.—Paralysis of serratus magnus (same case as in Fig. 27). Deformity increased by abduction of arms.

Fig. 29.—Paralysis of ulnar and internal cutaneous nerves.

Private M.—Gunshot wound of right arm at Somme; ulnar nerve sutured in England. Date of wound, 15/9/16. Admitted to Rotorua Hospital, 27/7/17; still in hospital.

*Condition on Admission.*—Scar of entry above the internal condyle of the humerus; exit just inside the biceps tendon; ulnar and internal cutaneous anæsthesia; wasting of the interossei; contracture of little and ring fingers; complete R.D. (In illustration, dotted line borders area of protopathic, continuous line that of epicritic loss. Note that the thumb is flexed, though the musculo-spiral is untouched. The freckling of the skin is due only to sunburn.)

*Treatment.*—Ulnar splint, galvanism, and massage.

Fig. 30.—Radial deviation of the hand.

Fig. 31.—Radial deviation corrected by poroplastic splint

FIGURE 32.

Private W.—Shell wound, left forearm, at Somme, carrying away the greater part of the shaft of the ulna. Date of wound, 15/9/16. Admitted to Rotorua Hospital, 13/3/17; discharged from hospital, 30/8/17.

*Condition on Admission.*—Large scar still unhealed, involving whole ulnar side of forearm from elbow to wrist; elbow can be bent but not fully extended; wrist flexed, and resists forcible extension; ulnar-nerve paralysis; trophic changes in nails of all the fingers.

*Treatment.*—As the ulnar nerve was destroyed throughout the whole length of the forearm, little could be done beyond removing sequestra.

(The shaded area marks the zone of anæsthesia; the continuous line, the edge of that of analgesia. It will be noted that in this case there was no anæsthesia of half the ring-finger, although the ulnar nerve was totally destroyed. Note also the characteristic position of the thumb.)

Fig. 32.—Ulnar-nerve deformity; *main-en-griffe;* thumb-flexion; trophic changes in nails. Protopathic anæsthesia limited by black line, epicritic by shaded area.

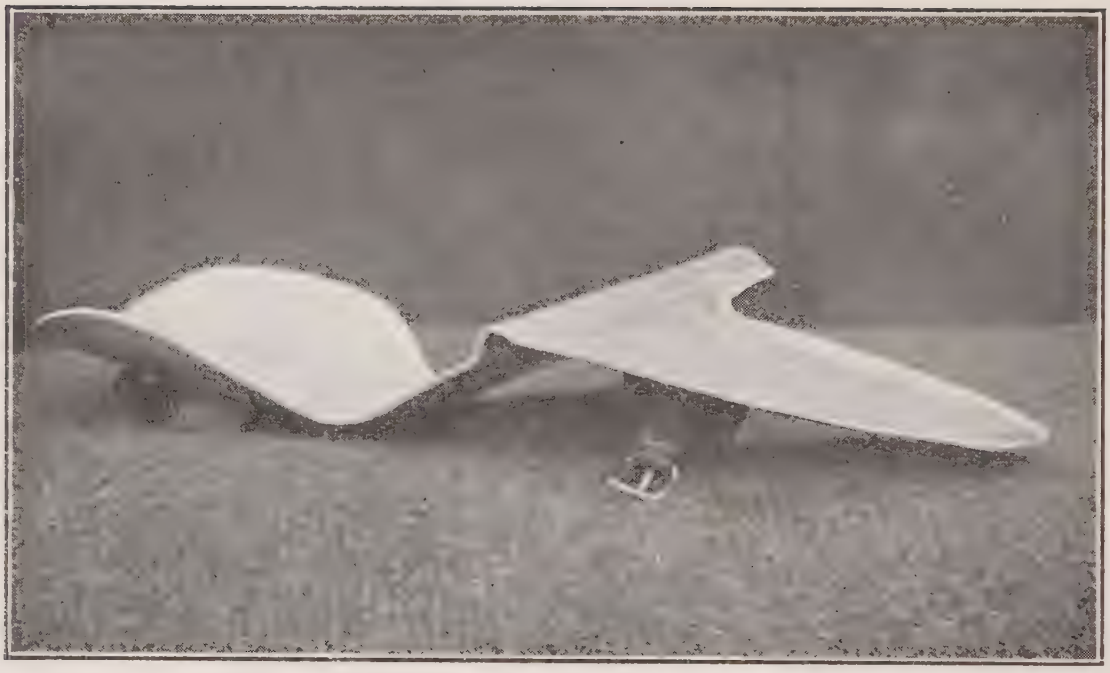


FIG. 33.—Ulnar-nerve splint. By imitating the action of the interossei it corrects the characteristic deformity. At the same time, it does not interfere with the action of the thumb and two normal fingers.

FIG. 34.—Ulnar-nerve splint with thumb-piece.

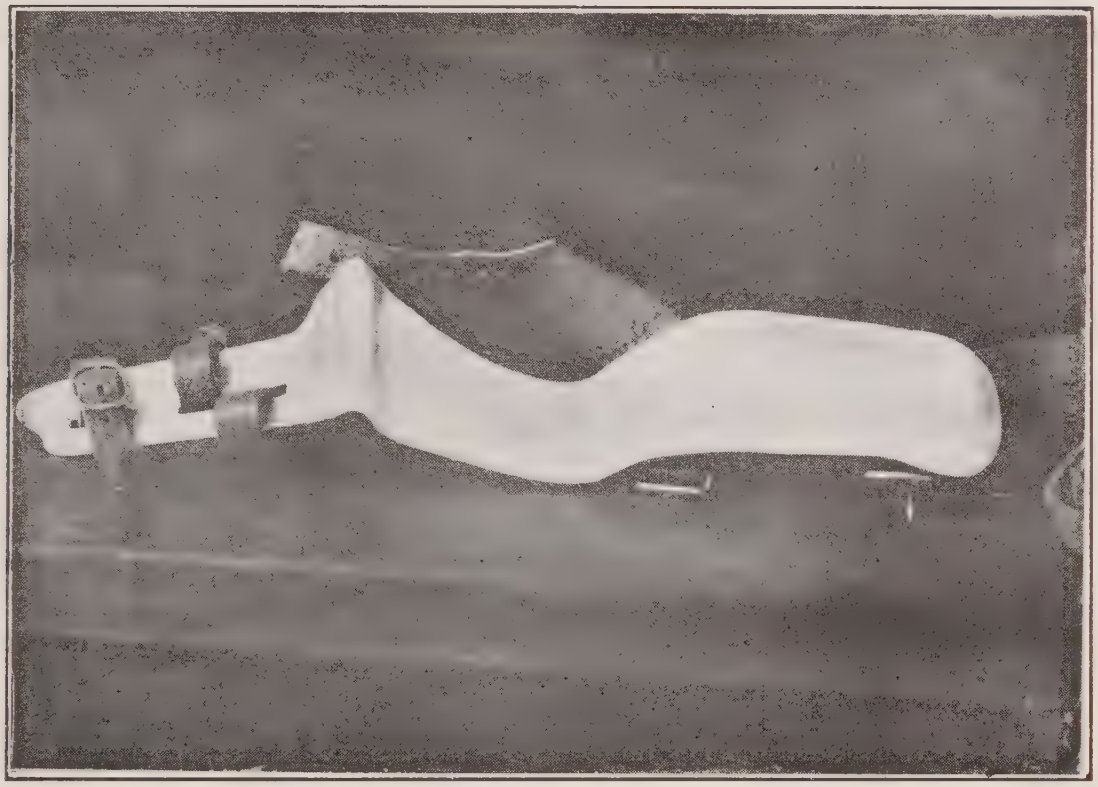


Fig. 35.—Ulnar-nerve splint for cases with contracture of ring and little fingers.

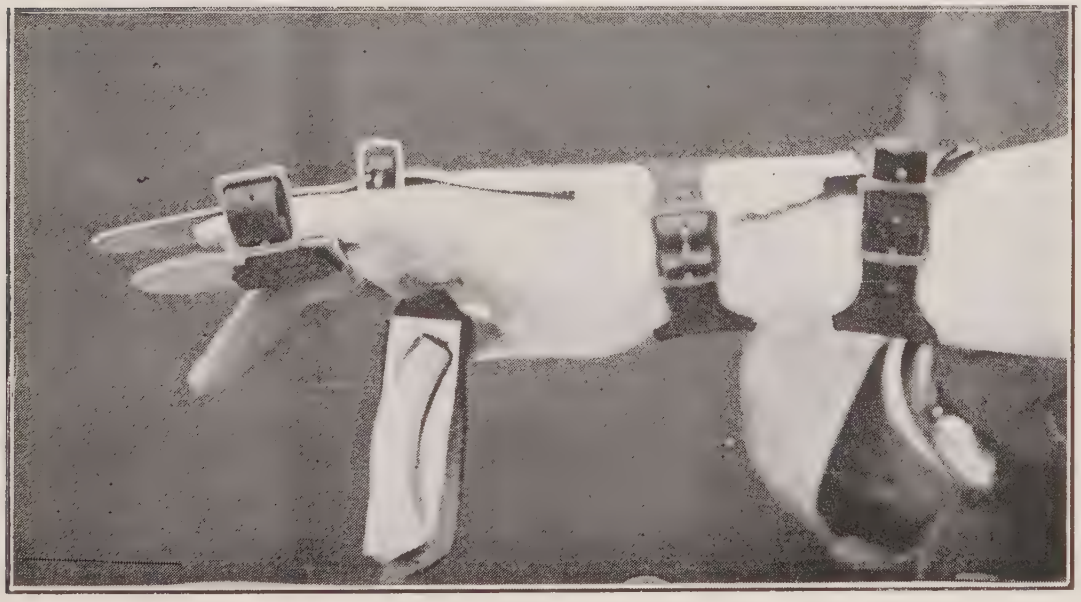


Fig. 36. (See Fig. 37.)

FIGURE 37.

The main dorsal splint is flexed at the metacarpo-phalangeal articulations; there is a pad over the palmar surface of these joints, and a straight splint along the flexor surface of the two affected fingers.

FIGURE 38.

Private P.—Gunshot wound of right shoulder at Somme; bullet entered anterior axillary fold and passed across the roof of the axilla, emerging through posterior axillary fold, and giving a glancing wound to side of chest; ulnar, musculo-spiral, and median nerves were damaged; in hospital complete reaction of degeneration was reported, and ulnar nerve was sutured; there was temporary hæmoptysis. Date of wound, 20/9/16. Admitted to Rotorua Hospital, 4/9/17.

*Condition on Admission.*—All wounds healed; hand held in typical ulnar-nerve position, with contracture of the radial flexors; almost complete ulnar anæsthesia, and complete paralysis of the ulnar muscles; median-nerve anæsthesia recovering, and a good deal of voluntary power of flexion of fingers and thumbs; elbow can only be extended to 120 degrees; thumb flexed and adducted; wrist flexed from median muscles contracture; radial deviation of the hand; shoulder-movements limited by adhesions in the axilla.

*Diagnosis.*—G.S.W. of brachial plexus; division of the ulnar nerve; concussion of median and musculo-spiral.

*Treatment.*—Aluminium splint; farado massage; baths.

*Progress.*—Median and ulnar sensation returning.

Fig. 37.—Splint for cases of ulnar-nerve paralysis, with severe dorsiflexion of the first phalanges and very obstinate contraction of the little and ring fingers.

Fig. 38.—Combined musculo-spiral, median, and ulnar paralysis. The wrist is "dropped," but the fingers are dorsiflexed at the metacarpo-phalangeal joint owing to interosseous paralysis, and the fingers cannot be extended. Median contracture emphasizes and makes permanent the wrist-drop.

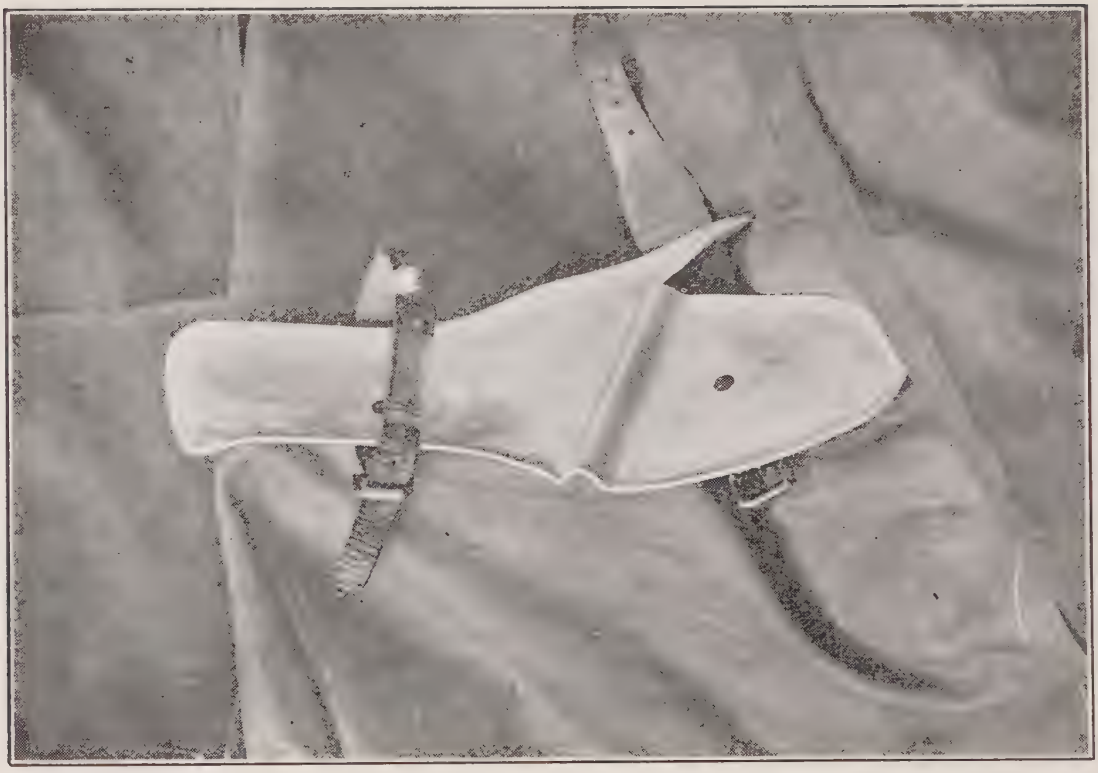


Fig. 39.—Splint for combined musculo-spiral and ulnar-nerve paralysis.

The splint has the ulnar ridge, and the finger-piece and palm are dorsiflexed. The thumb-piece should be slightly palmar-flexed, not dorsiflexed, to accommodate the normal direction of the thumb. This splint differs from the simple musculo-spiral splint in that in the latter the ulnar ridge is omitted and the whole splint more dorsiflexed from the wrist.

FIG. 40.—A simple and inconspicuous form of sling which is suspended from a button of the tunic. It is useful for men on light duty who need to rest the forearm part of the day.

Fig. 41.—A comfortable form of sling for cases in which there is tenderness about the neck and shoulders.

The supporting-straps are passed through slits in the seams of the tunic, hidden by the shoulder-straps, and are attached either to the braces or to the back trouser-buttons. They thus pass over a spot rendered less sensitive by the habitual pressure of the braces.

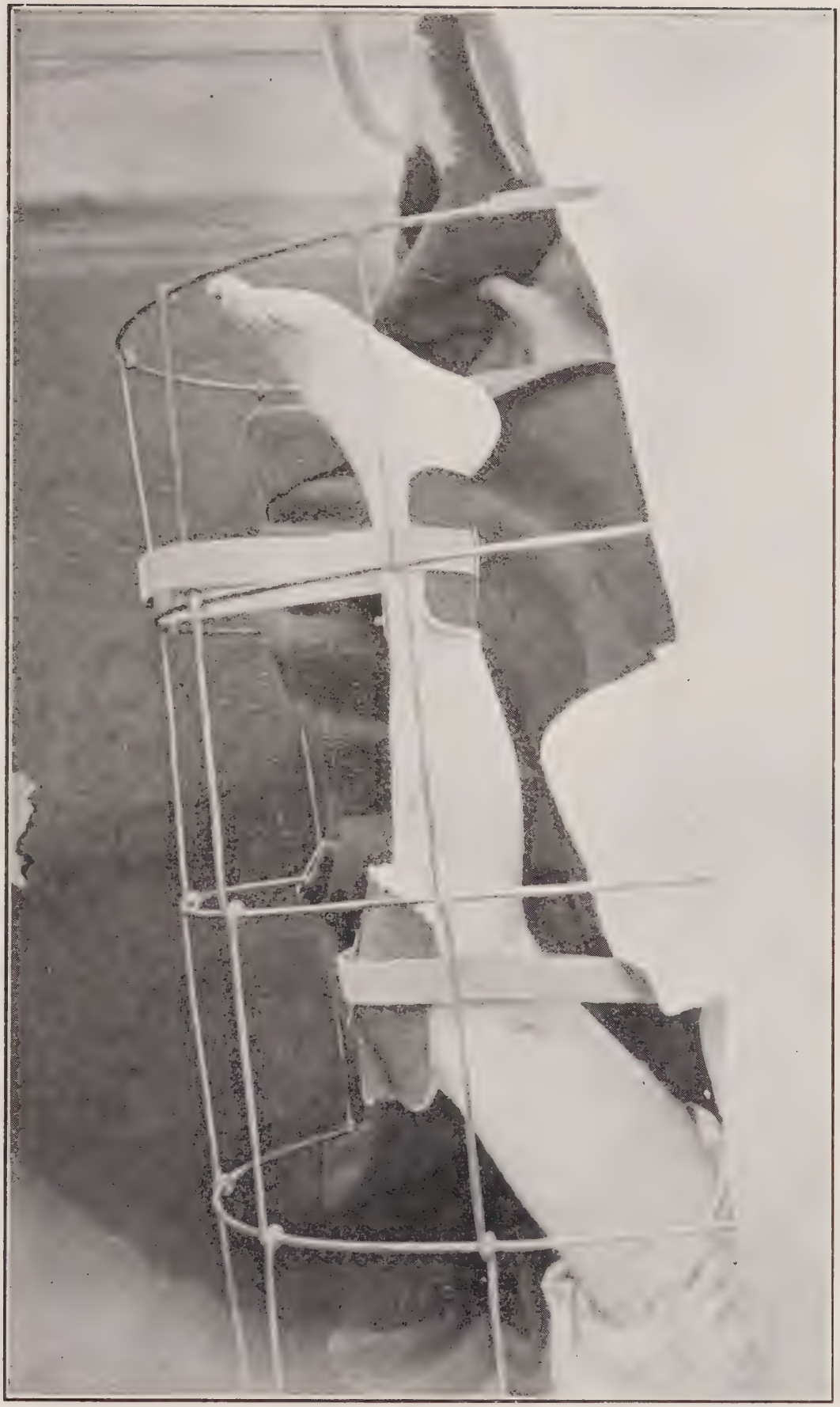


FIG. 42.—Elastic tension to counteract contraction flexion of knee.

FIG. 43.—Functional contracture of hand, radial view.

FIG. 44.—Functional contracture of hand, ulnar view.

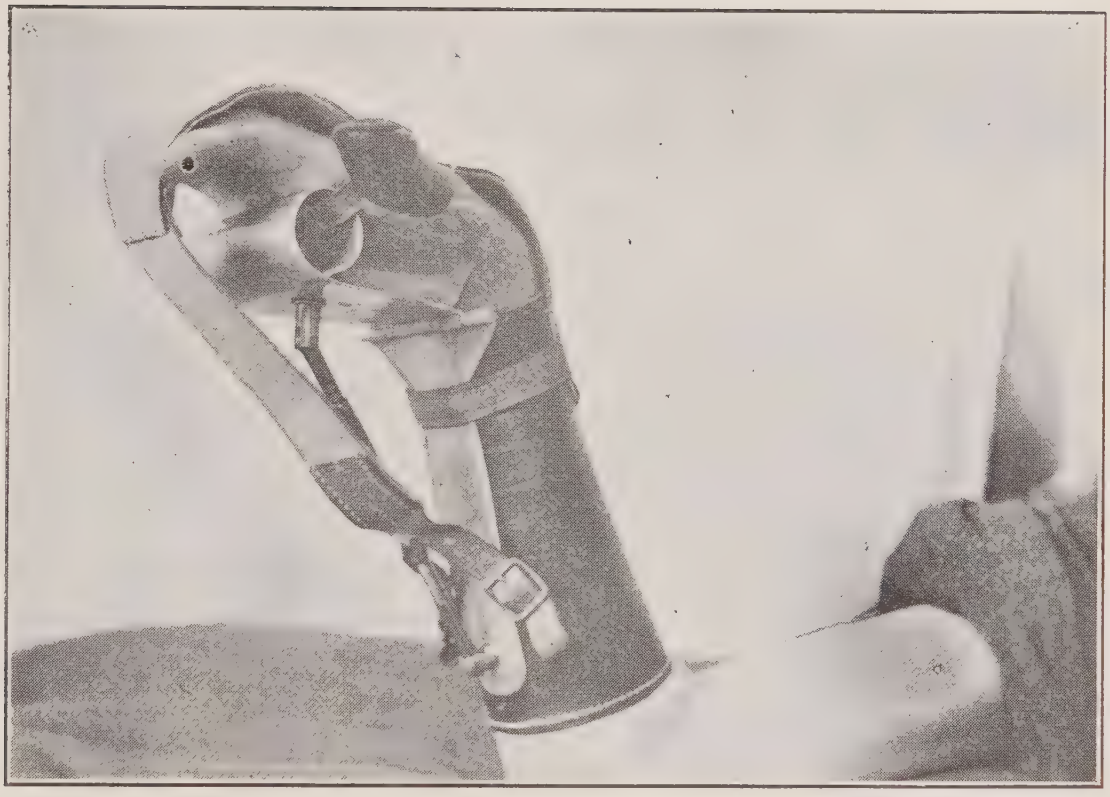


Fig. 45.—Apparatus to correct deformity of case shown in Figs. 43 and 44.

As the deformity was of long standing, considerable force was necessary to overcome the secondary contractures. The splint was a combination of screw force, elastic-band force, and rigid support, as at the thumb-piece. The deformity was fully corrected while in the splint, but tended rapidly to relapse.

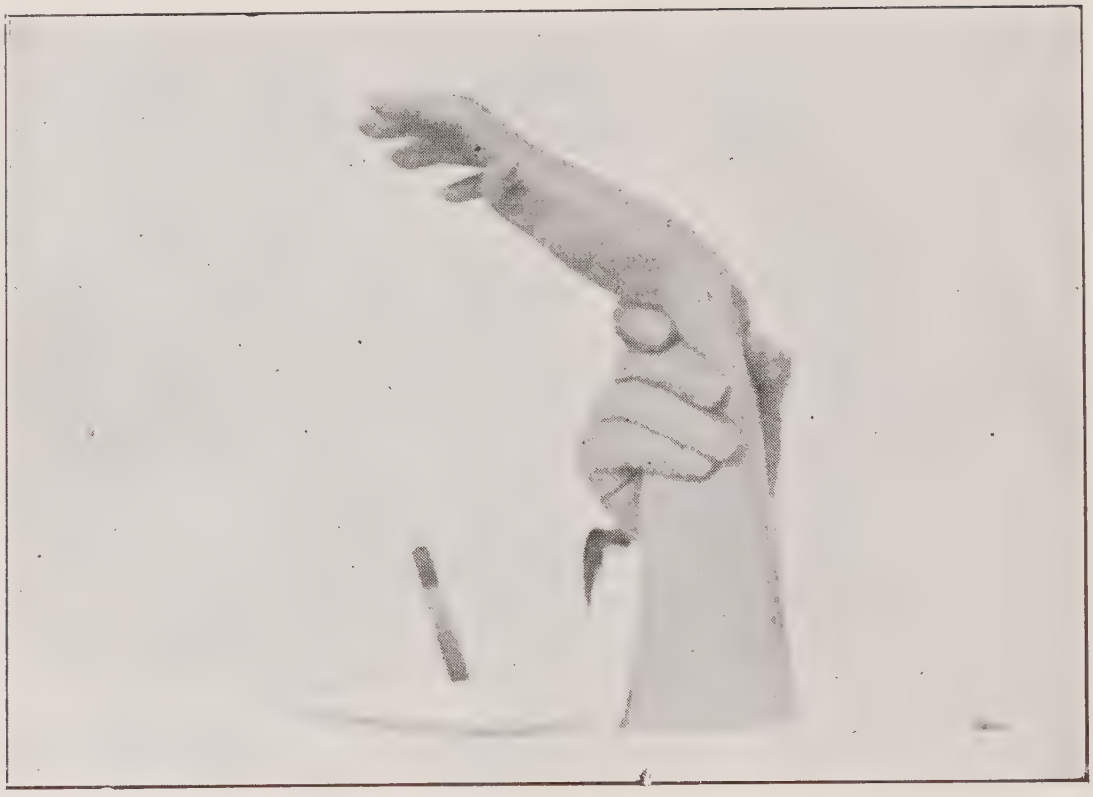


Fig. 45A.—The hand shown in Figs. 43 and 44, under deep chloroform anæsthesia.

This case answered accurately to Babinski's description of "reflex contracture," exhibiting the characteristic phenomena which he terms "physio-pathic." Thus, as anæsthesia deepened, the contracture gradually though not completely disappeared, while the muscles continued to show hypertonus. With the disappearance of rigidity it was possible to elicit the exaggerated tendon reflexes—*e.g.*, the exaggerated wrist-jerk — while the muscles of the forearm showed increased irritability to mechanical stimulation, contracting on percussion with the finger. On recovery from the anæsthetic the contracture reappeared, and had to be corrected by plaster-of-Paris, a subsequent anæsthetic, and further splinting.

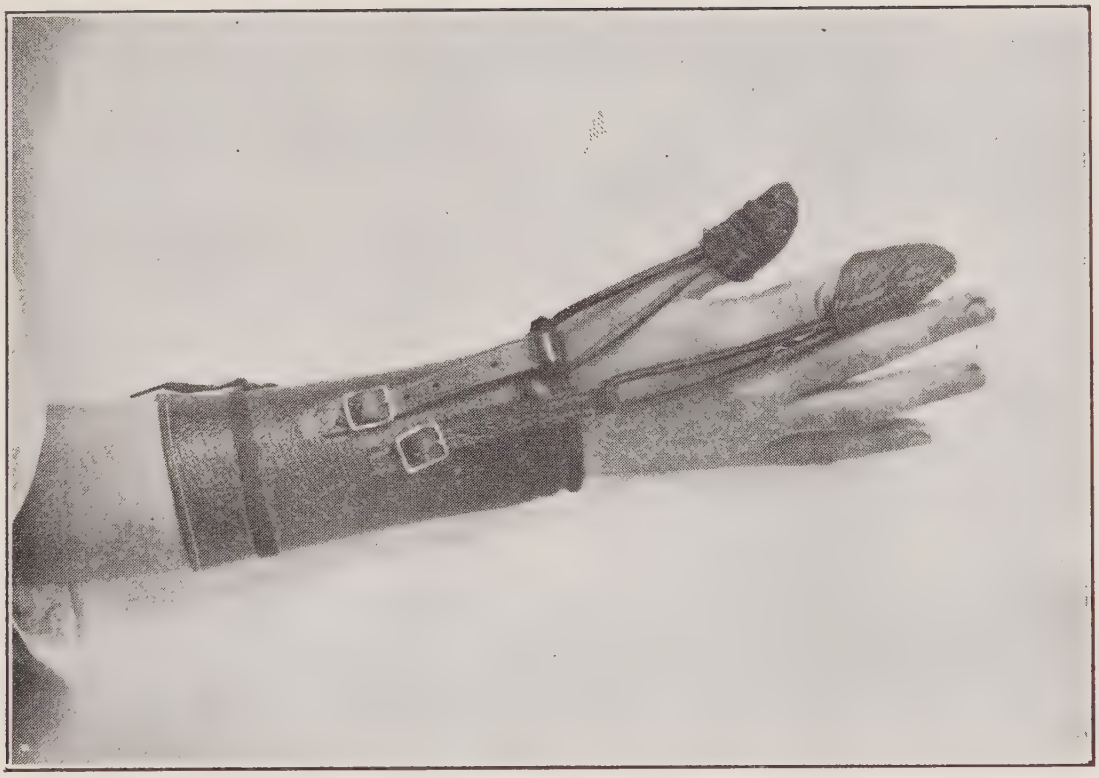


Fig. 46.—Modified Souttar glove for recovering musculo-spiral paralysis. The long extensors of the thumb and forefinger alone required treatment.

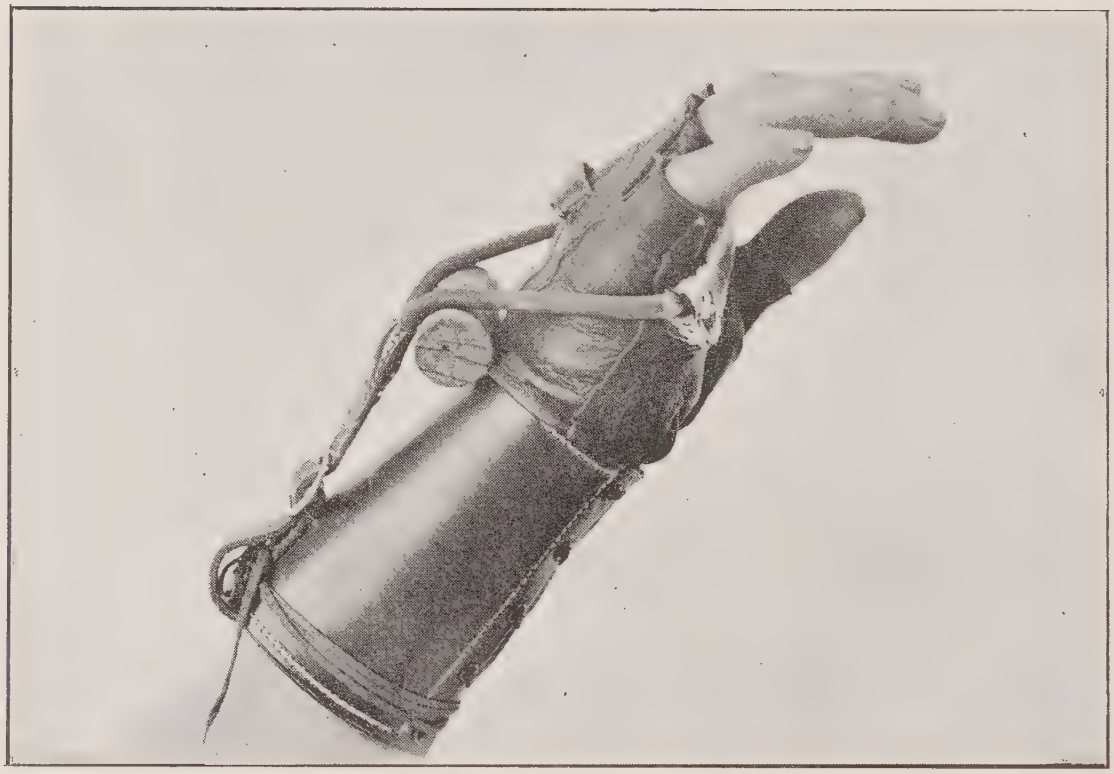


Fig. 46A.—Elastic support in wrist-drop.

As some power of extension was returning in the fingers, apart from the interosseous extension of the two distal phalanges, and as it was desirable that the hand should be *used* as far as possible, a rigid "D piece" was placed so as to prevent flexion of the first phalanges and cause slight dorsiflexion of the wrist. This "D piece" should be sewn to the glove to prevent slipping. In the figure it was not sewn, and had slipped towards the metarcarpo-phalangeal joints. The angle of pull of the rubber was increased by the insertion of a cork, and the degree of dorsiflexion could of course be increased by tightening the strap.

This support, while preventing deformity, interferes remarkably little with the movement of the hand, and is therefore preferable in many cases to any form of rigid splint.

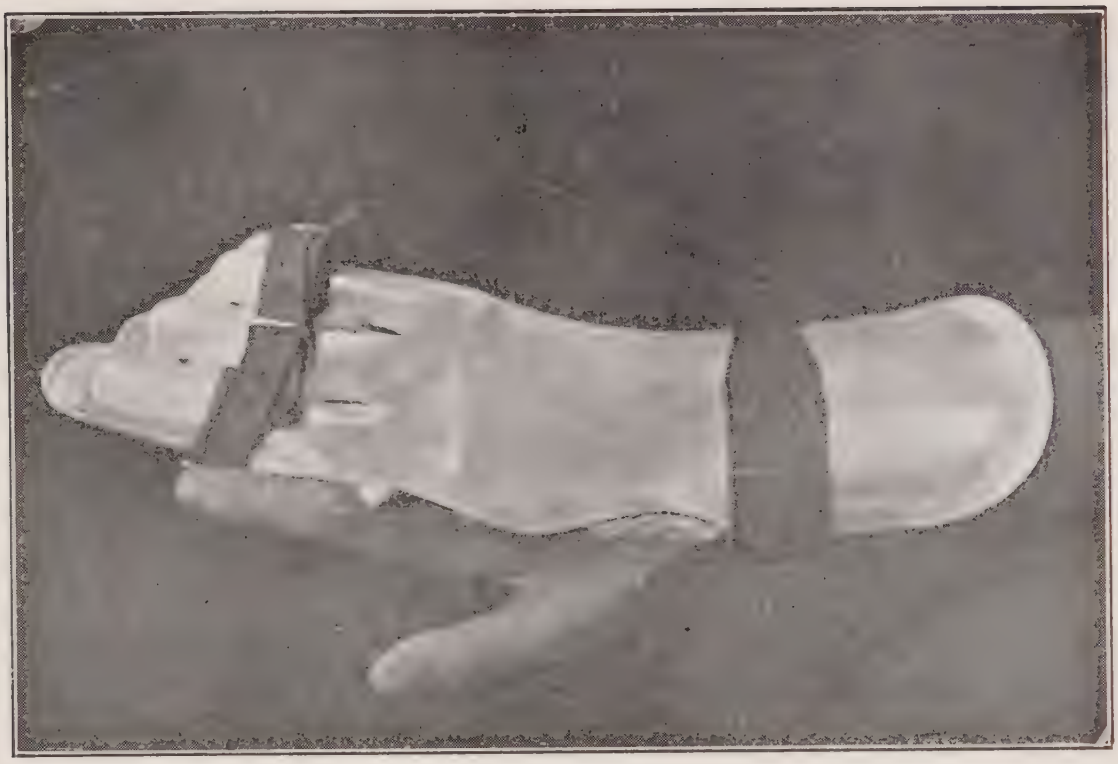


Fig. 47.—Trifurcated aluminium splint for very severe contracture of long flexors of fingers : dorsal view.

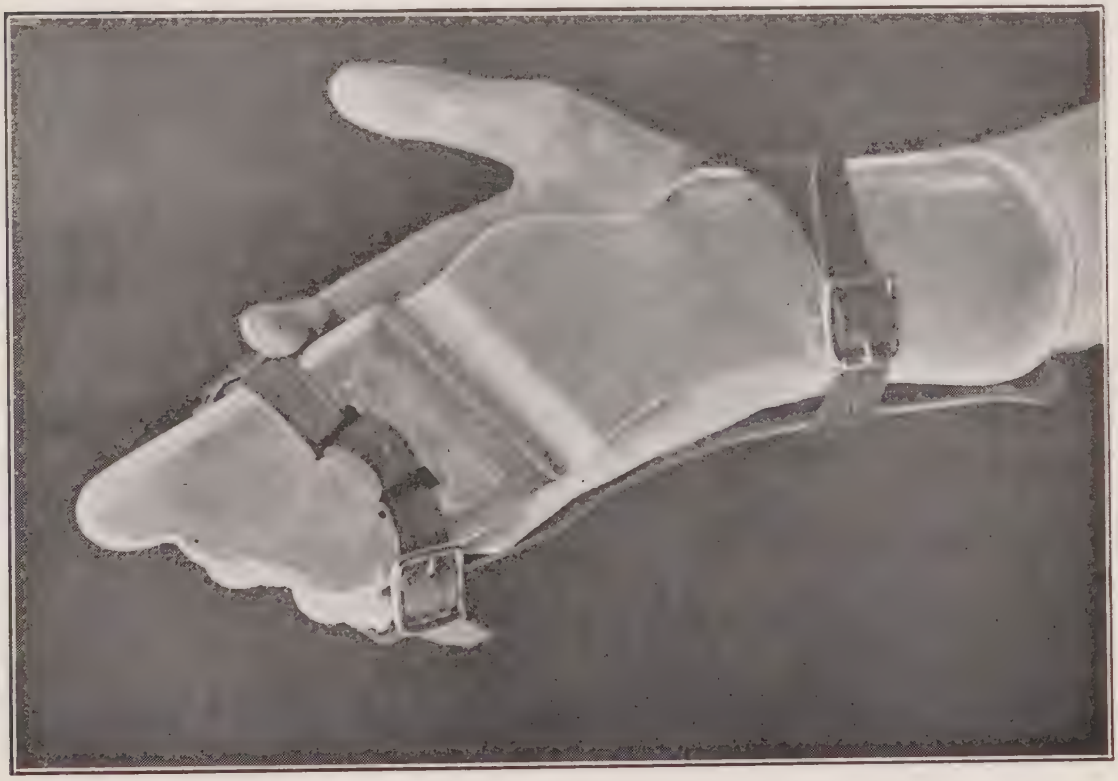


Fig. 48.—The same splint : palmar view.

FIGURE 49.

Captain G.—Shrapnel wound, right arm, at Somme; wrist-drop for two months. Date of wound, 15/9/16. Admitted to Rotorua Hospital, 18/6/17; discharged, 12/9/17.

*Condition on Admission.*—Wrist-drop recovered, but still paresis of extensor communis digitorum. There is still a powerful tendency to flexion of the wrist, kept up by contracture of the long flexors, and only overcome by the exertion of considerable force. The flexor muscles of the forearm are hard and rather hypertrophied, and voluntary flexion of the fingers is impossible.

*Treatment.*—Aluminium cock-up splint; faradic and galvanic currents. Great improvement for about three hours after each treatment, and best results from faradic current.

*Result.*—Recovery of both flexion and extension.

FIG. 49.—Median-nerve injury: contracture of flexor muscles.

FIG. 50.—Paralysis of abductor pollicis and extensor ossis metacarpi pollicis (median and musculo-spiral wound).

FIG. 51.—Poroplastic splint invented by the patient to correct his deformity (Fig. 50).

Fig. 52.—Firm contracture of fingers.

Fig. 53.—Plaster-of-Paris mass-mould method of overcoming contracture (Fig. 52).

FIGURE 54.

Private M.—Shell wound, left arm, at Somme; compound fracture of humerus; injury to musculo-spiral and median nerve.

*Condition on Admission.*—Musculo-spiral recovered; median, anæsthesia and paralysis complete; marked trophic changes of whole hand, but especially nails in median area.

*Treatment.*—Farado massage and interrupted galvanism, with Bier's bandage three times a day followed by massage; hot-air bath to hand.

*Result.*—Very slow median recovery, first, of sensation and then of power. The tropho-neurosis responded to Bier's treatment.

FIG. 54. — Tropho-neurosis of hand: Median-nerve paralysis, hypertrophic variety.

FIGURE 55.

Private McP.—Machine-gun wound of left arm at Gallipoli, 25/4/15; the wound was not dressed for three days, and became very septic. Operation, 9/5/16, at Dunedin; 4 in. of ulnar nerve found destroyed, but anatomical continuity restored by suture, and median nerve freed from a mass of scar tissue. Admitted to Rotorua Hospital, 25/7/16; discharged from hospital, 22/11/16, "very much better."

*Condition on Admission.*—Anæsthesia of the left ulnar-nerve area, with atrophy of all the muscles of the hand; continuity of the ulnar nerve shown by the fact that pressure over the extreme upper point of the operation scar caused pain at the tip of the little finger, and by electrical tests; there was also some burning pain of the tip of the little finger. The most noticeable feature of the case was the atrophic condition of the hand, with very tapering fingers. Another noticeable feature was an extremely painful condition, "causalgia," of the ulnar area excited by reflex disturbance. At first this was thought to be a pure neurosis, but gradually the opinion was arrived at that it was due to extreme susceptibility to "frictional electricity." Thus a touch on the bare feet or the *dry* right hand used to cause immediate intense pain in the left ulnar distribution. On a dry hot day this symptom was very noticeable, but was not observable on a damp day. In less degree this condition has been noticed in nearly all patients with causalgia; and the thought suggests itself that the pain which so many rheumatic people feel *before* rain, which passes off as soon as the rain begins to fall, may have some such similar physical basis.

*Treatment.*—Very gentle farado massage: Bier's bandage.

*Condition on Discharge.*—Distinct sensation to touch returned over whole ulnar area.

Fig. 55.—Tropho-neurosis of hand : Ulnar-nerve paralysis, atrophic variety.

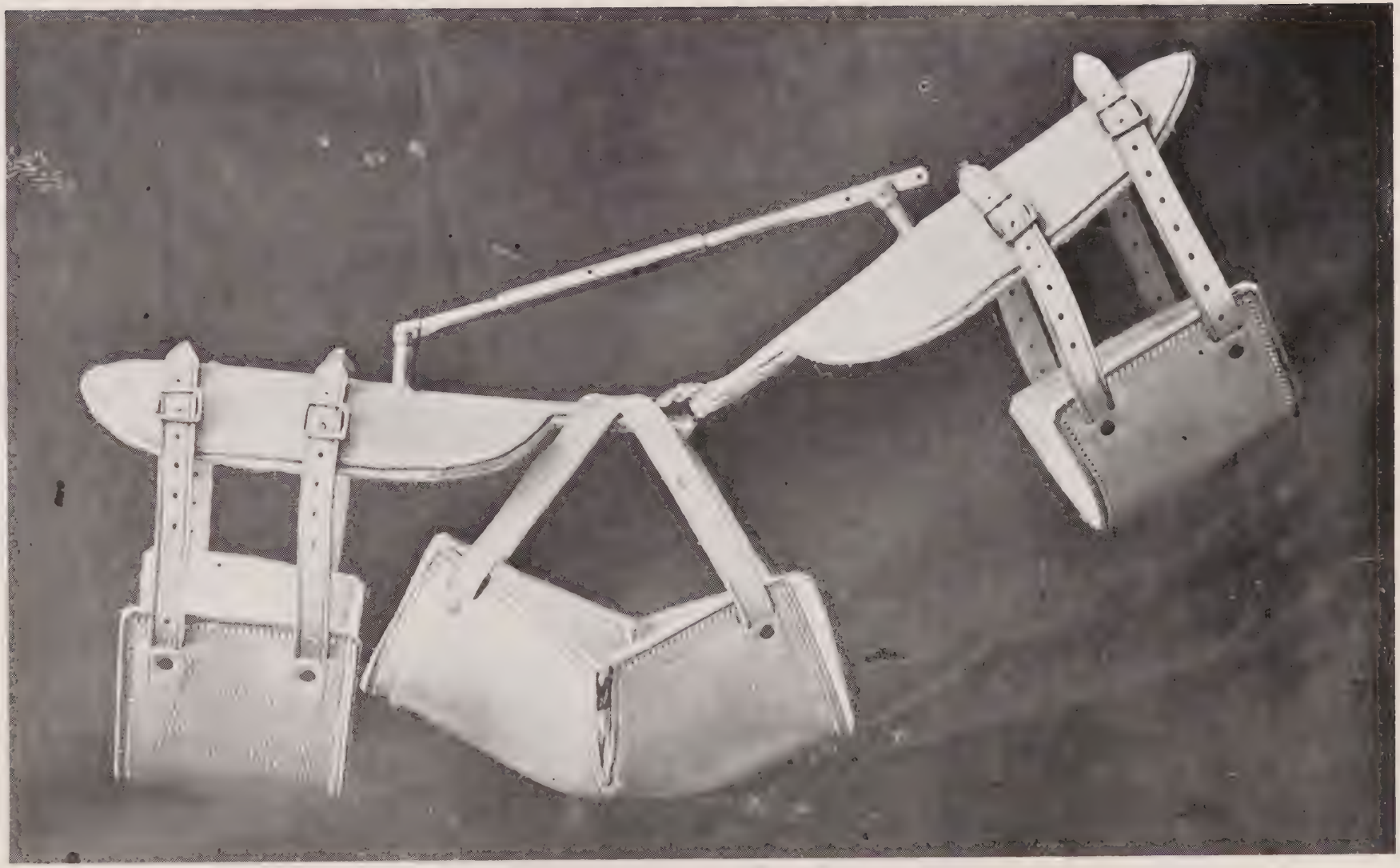


Fig. 56.—Screw extensor (walking) knee-splint.

This splint can be worn under the trousers. Flexion and extension to large degrees can be altered by removing the split pin in the extensor-rod to another hole. Gradual extension can be effected by means of the female screw in the rod, rotated by inserting a wire nail in the central hole.

FIG. 57.—Corn-cob handles for knife and fork for patients unable completely to close the hand. The large grip and rough surface of these handles make them very easy to grasp—and they cost nothing.

Fig. 58.—Orthopædic machine: "Active" extension of knee-joint.

Fig. 59.—Orthopædic machine: "Active" extension of elbow-joint.

FIGURE 60.

1. Rowing-boat.
2. Stationary bicycle with resistance gear and cyclometer.
3. Nautical wheel.
4. Pronation and supination resistance handles.
5. Resistance wrist-rollers for flexion and extension of wrist.

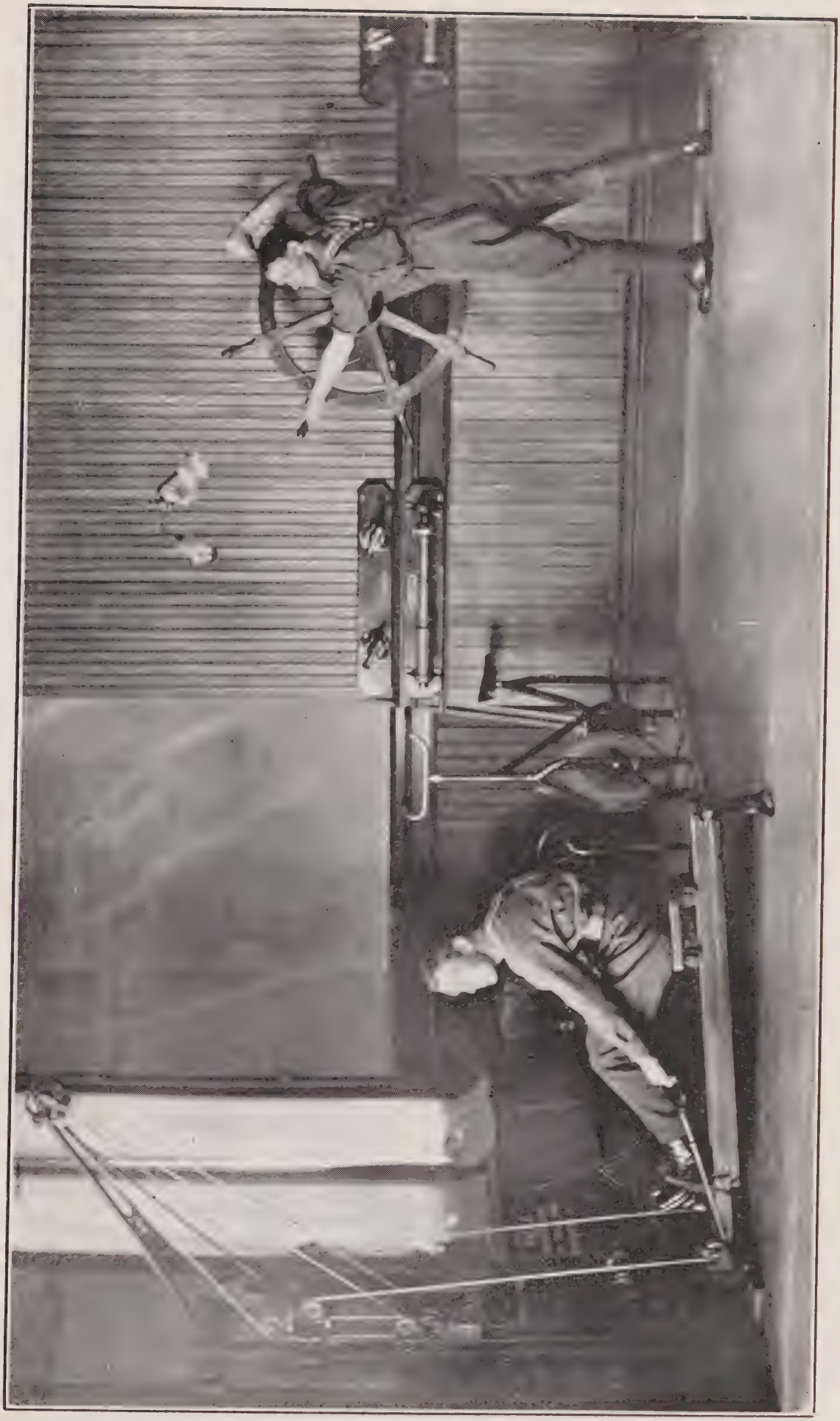


FIG. 60.—Physical orthopædic machines

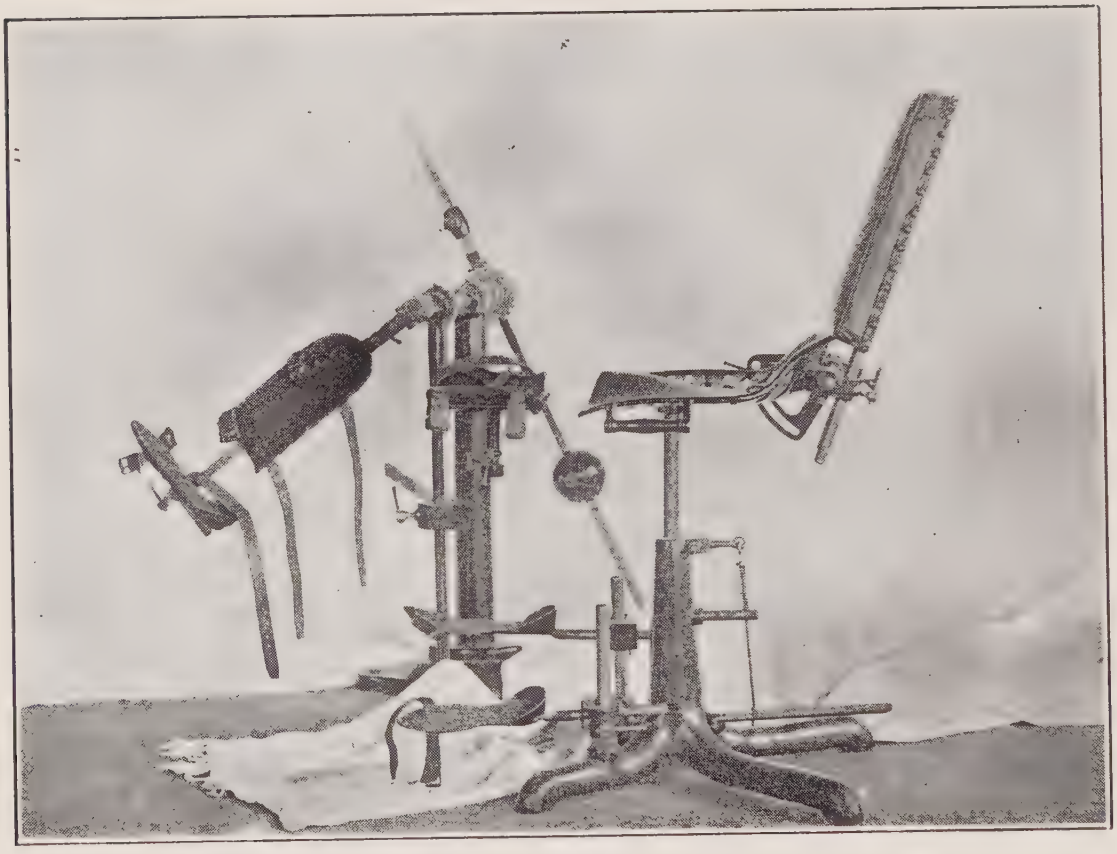


Fig. 61.—Orthopædic machine for "active" movement of any of the limb-joints.

Fig. 62.—Paralysis of the left cervical sympathetic.

This case, while not coming strictly within the compass of this work, is added for its intrinsic interest. It shows admirably the cardinal symptoms :—

(1.) Enophthalmos, from paralysis of the fibres of Müller.

(2.) Pseudo-ptosis—that is, drooping of the upper lid, which can, however, be raised by voluntary effort.

(3.) Contracted pupil, which does not dilate when shaded, but contracts further to light and accommodation.

# APPENDIX I.

The following diagrams will, it is trusted, save the busy clinician the time needed to hunt through many text-books.

A very brief investigation will convince the searcher how difficult it is to bring the various authorities into accord in regard to the distribution of sensory nerve areas.

In the diagrams here given an endeavour has been made to obtain the average view, and this has been corrected only in such instances —*e.g.*, in the external popliteal nerve—as experience of many cases of gunshot wound has shown to be erroneous.

The diagrams of the main ramifications of the nerve trunks are given because they have proved of such practical utility to the author himself and to fellow-workers, though they are merely a restatement of the ordinary anatomical facts of the text-books of anatomy, and make no pretence to any originality.


FIG. A 1.—Front of arm : Root areas.

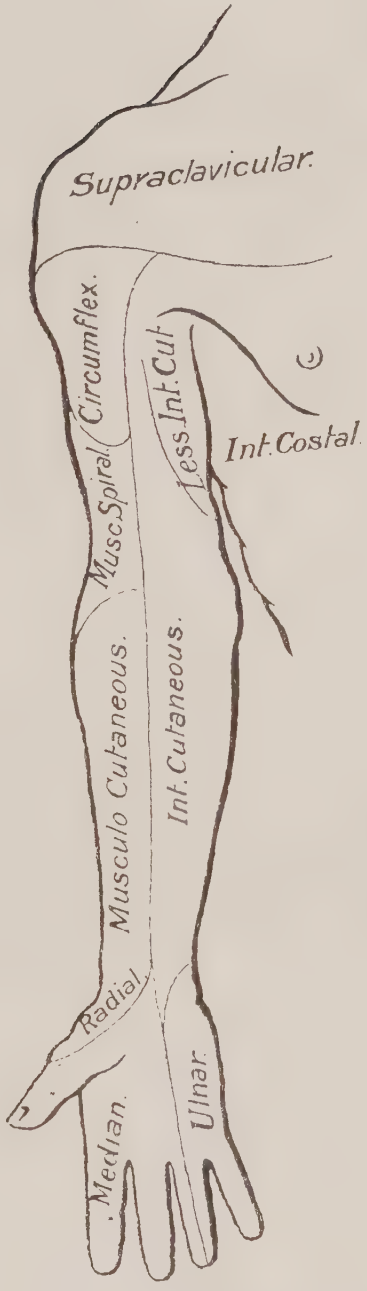



FIG. A 2.—Front of arm : Sensory nerve areas.


FIG. B 1.—Back of arm: Root areas.

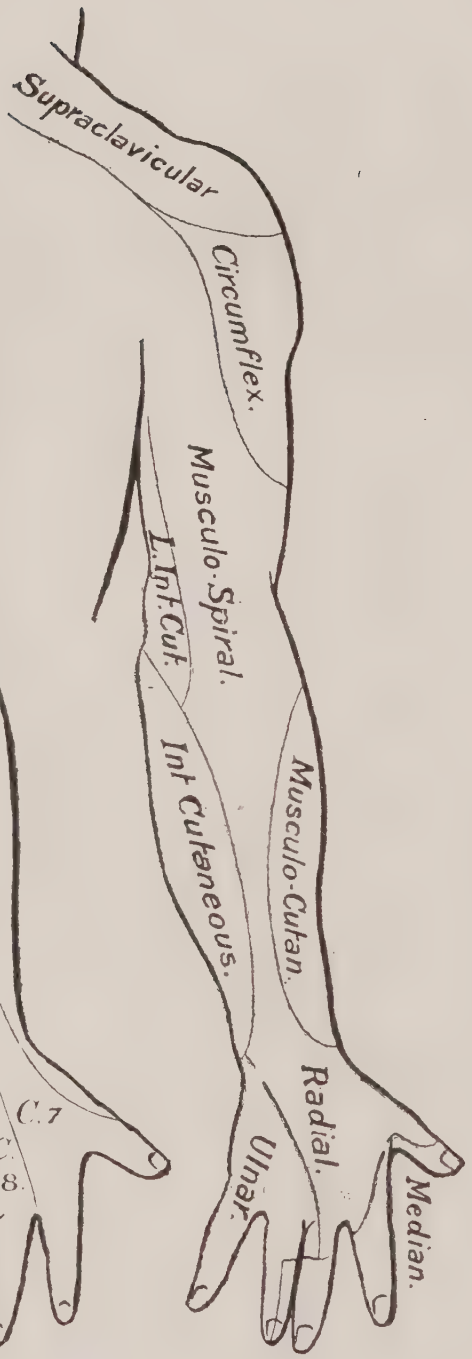



FIG. B 2.—Back of arm: Sensory nerve areas.

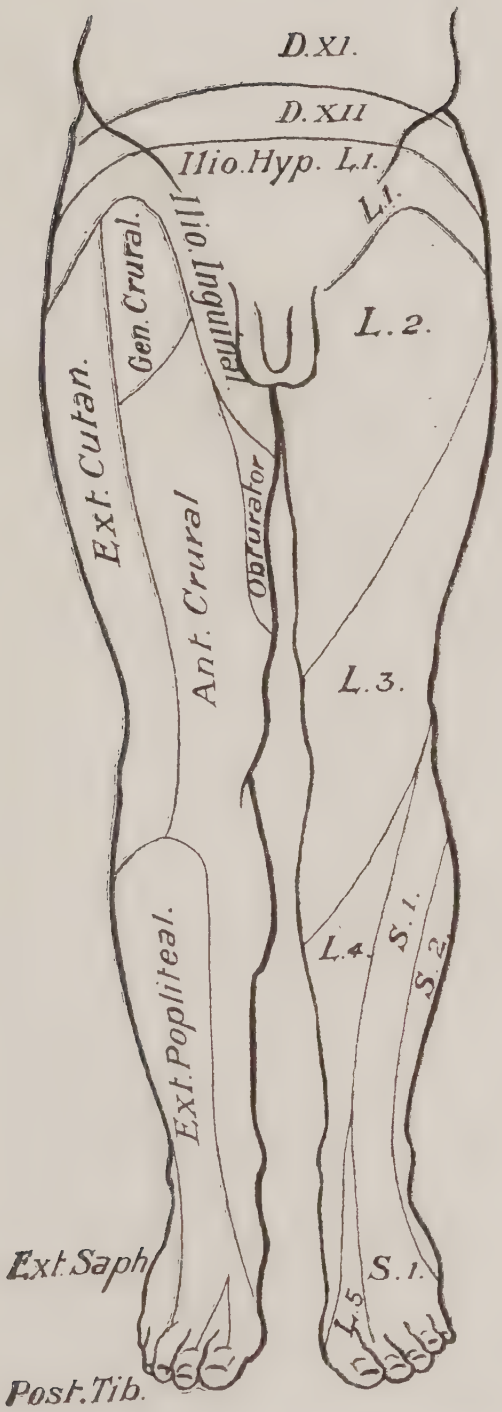



FIG. C.—Front of lower limbs: Sensory nerve segmental areas.

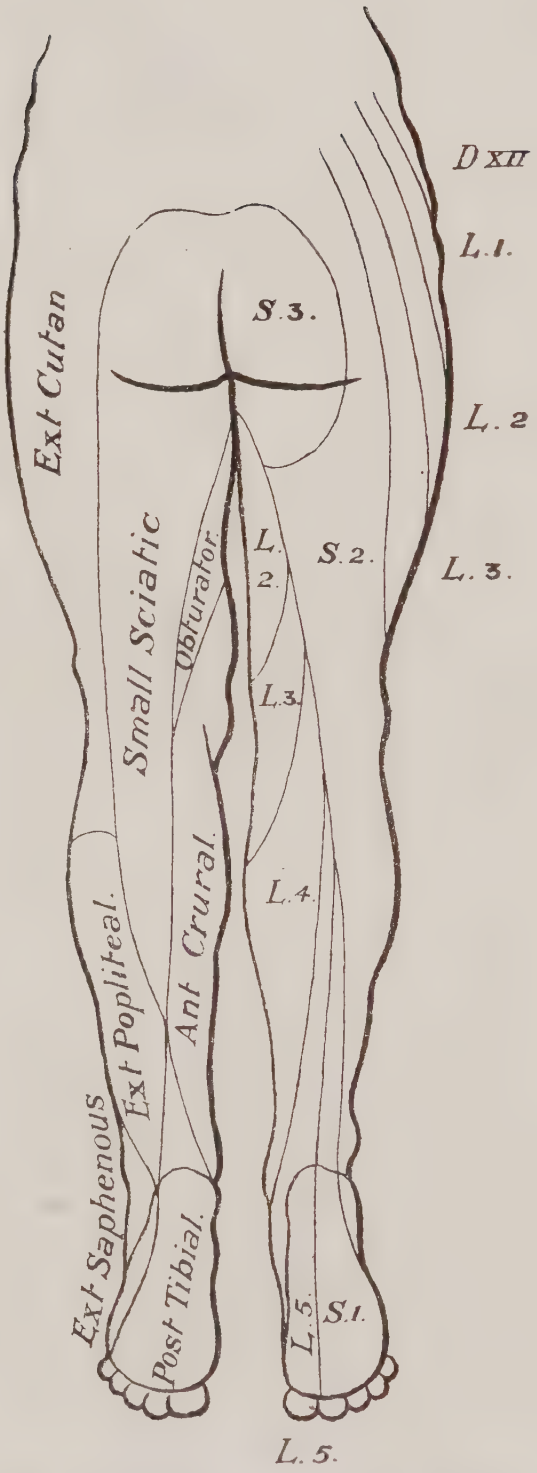
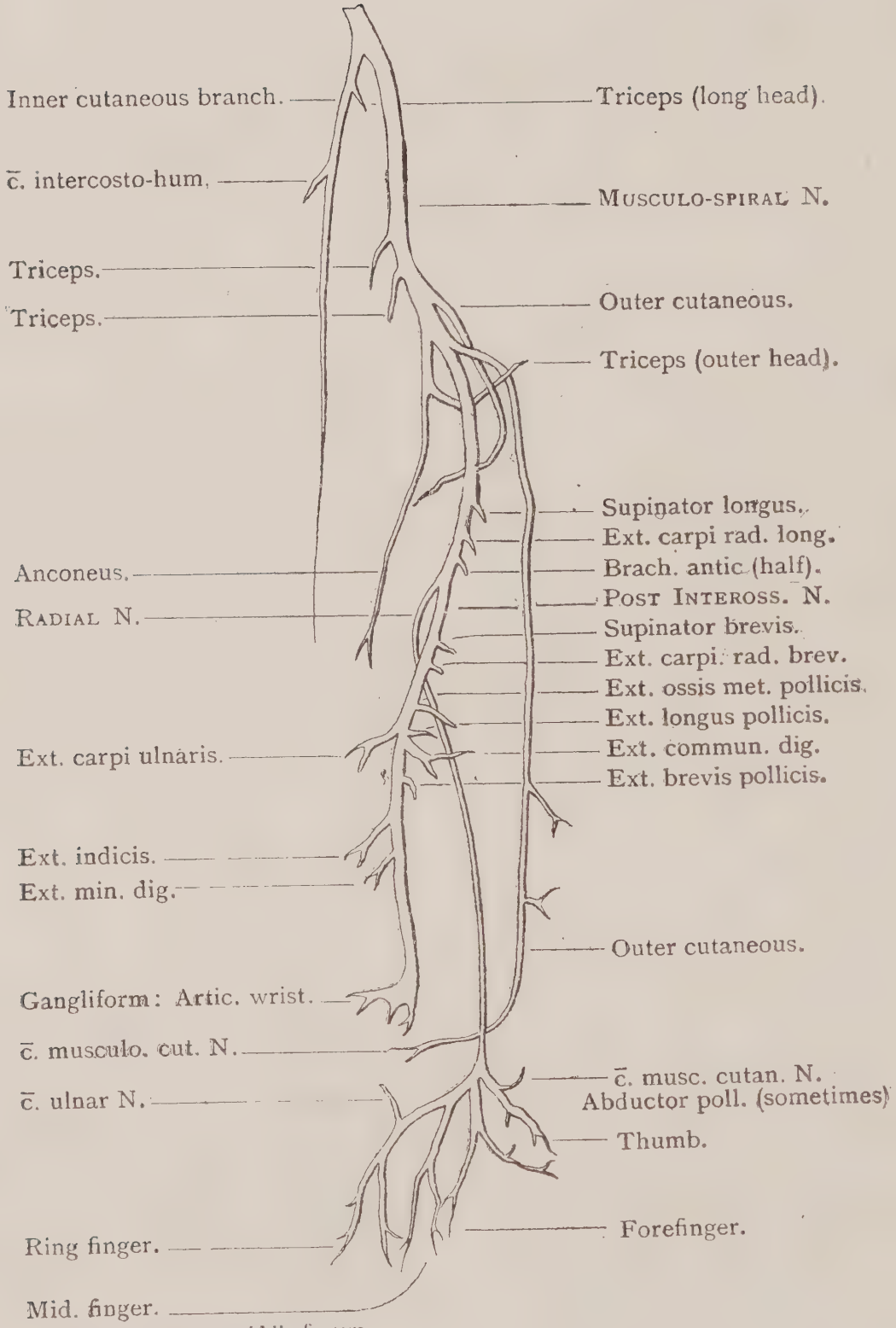



FIG. D.—Back of lower limbs: Sensory nerve and segmental areas.




N.B.—In the three middle fingers the dorsum of the two terminal phalanges is supplied by the palmar branches of median and ulnar nerves.

Fig. E.—Musculo-spiral nerve.

Post. Cord.

C vi, vii, viii. D i.

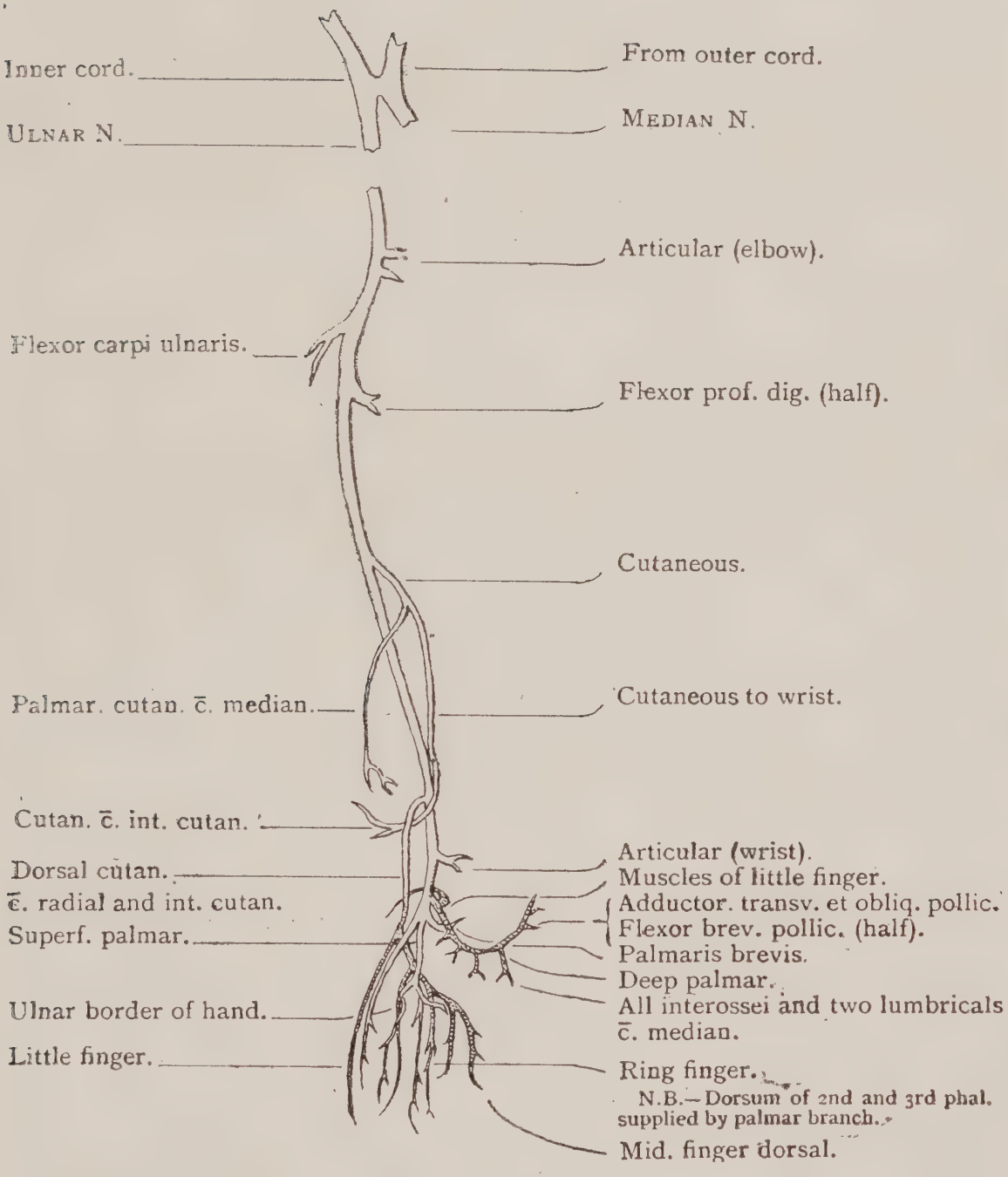



Fig. F.—Ulnar nerve.

Ulnar Nerve, Inner Cord: C VIII, D I.

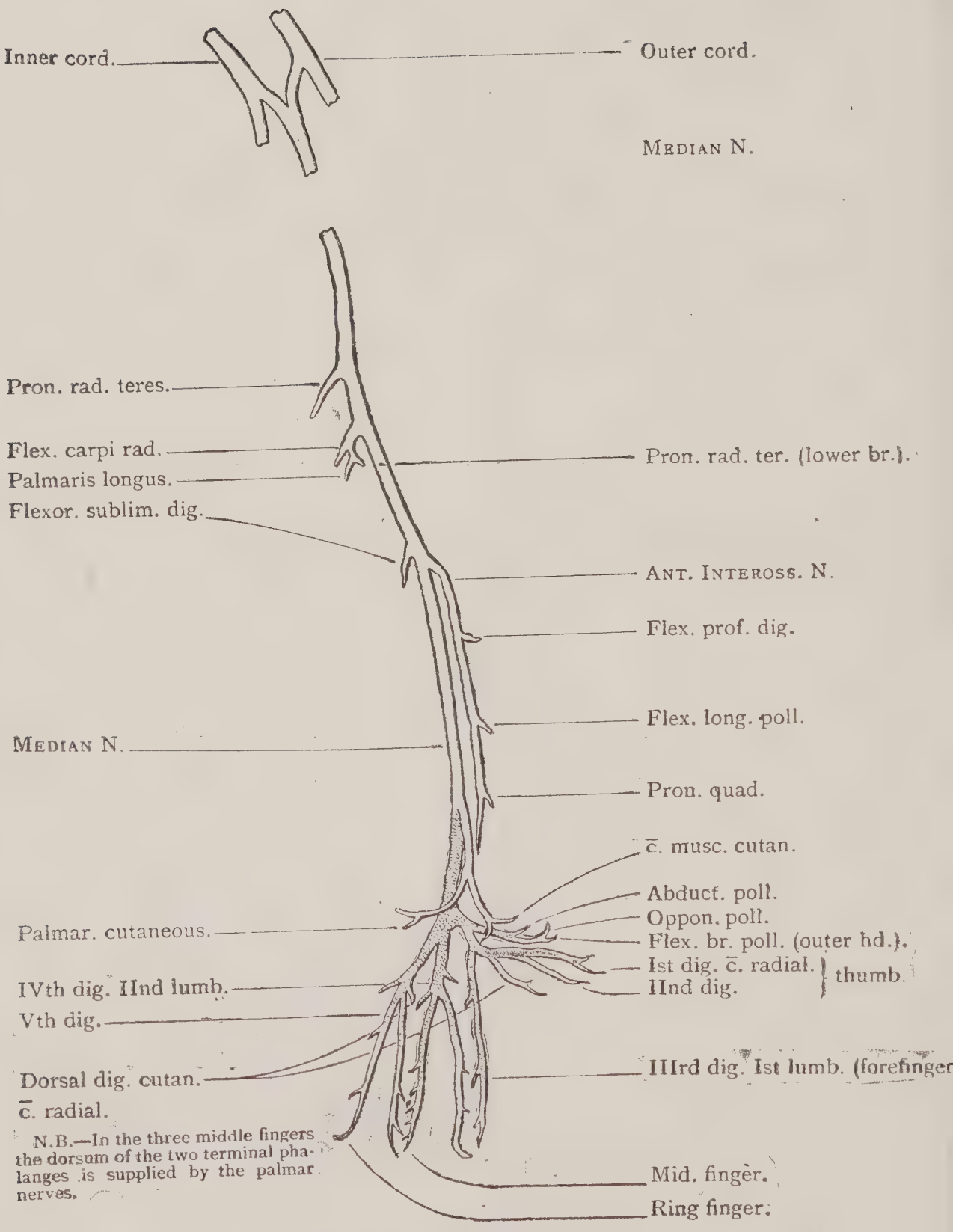



Fig. G.—Median nerve.

C vi, vii, viii. D i.

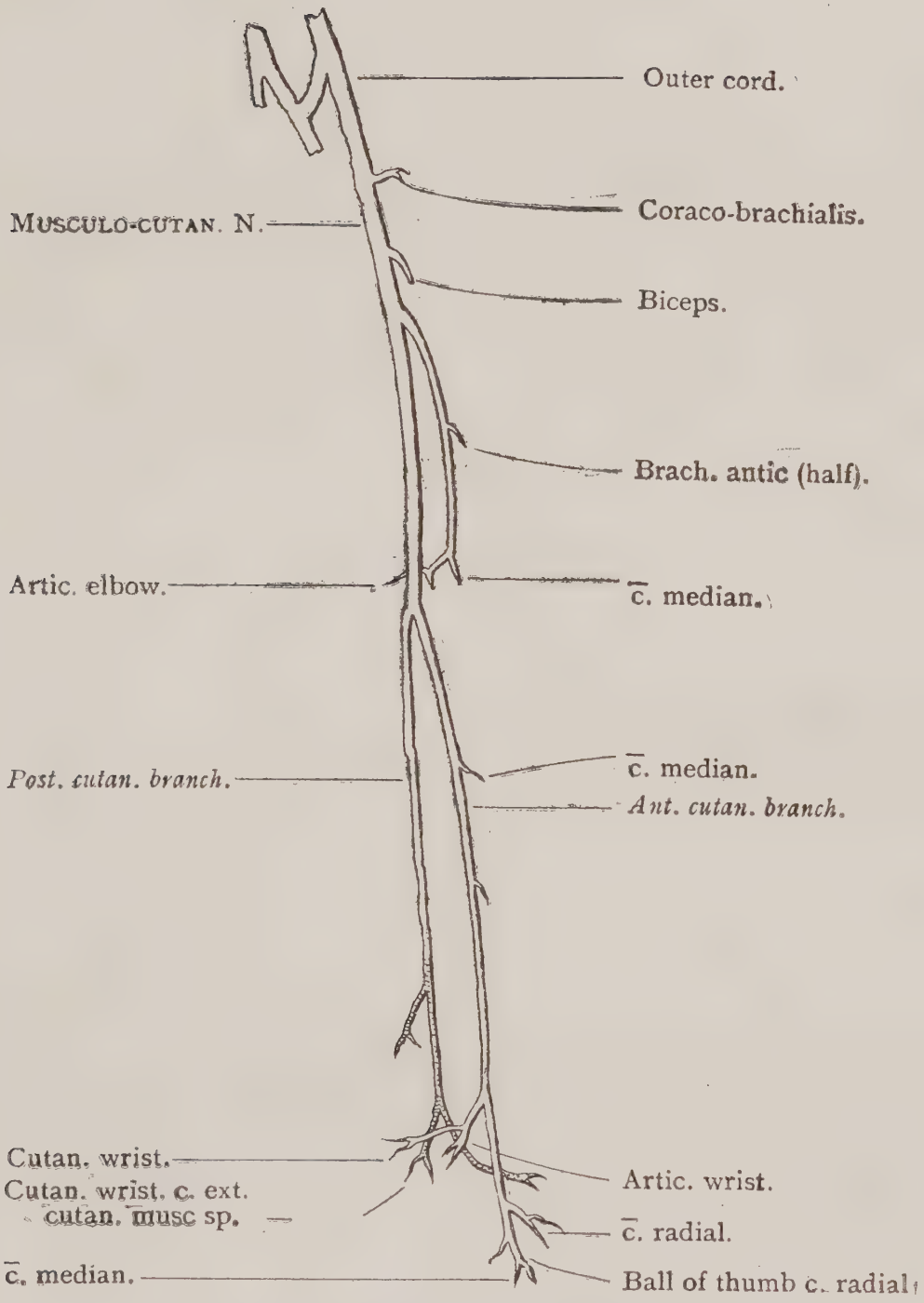



Fig. H.—Musculo-cutaneous nerve.

C v, vi.

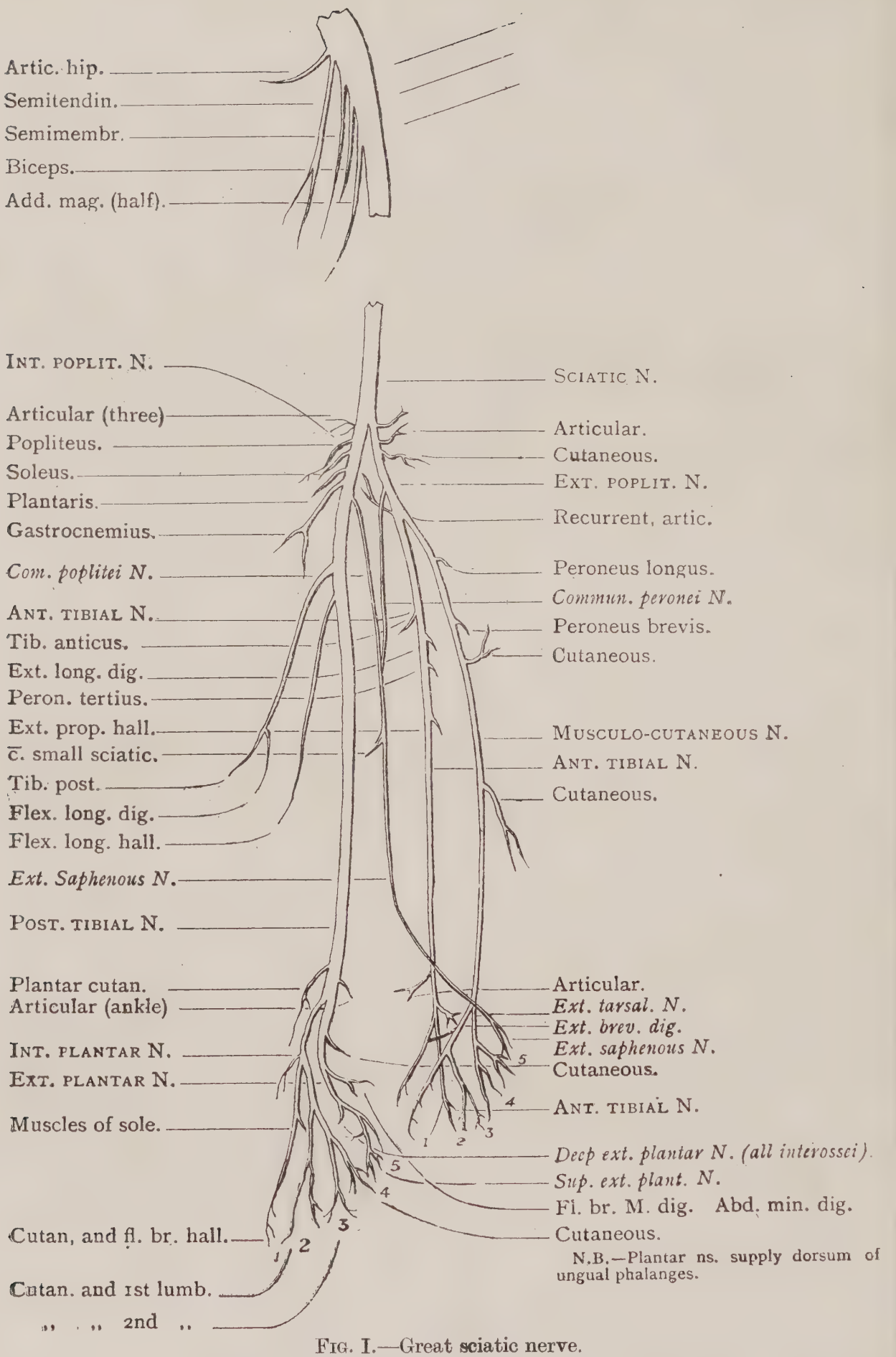



FIG. I.—Great sciatic nerve.

L IV, V (Lumbo-sacral Cord): S I, II, III, and part of S IV.

# APPENDIX II.

## EXPLANATION OF PHENOMENA OF REACTION OF DEGENERATION AND REACTION AT A DISTANCE (LONGITUDINAL REACTION).*

THE following diagrams may serve to explain the rationale of these reactions, also the importance of the motor point in testing muscles. It must first be premised—

(1.) That, except in late stages, a muscle cut off anatomically or physiologically from its nerve-supply exhibits hyper-excitability to galvanism as well as to mechanical stimulation (idio-muscular reflex), and is especially susceptible to a diffuse current:

(2.) That the negative pole alone is effective in "closing current" for muscle, as it is for nerve.

In the diagrams N represents nerve; M T muscle, T being its tendinous insertion; the point of junction of nerve and muscle is the motor point; where the nerve is interrupted the motor point is shown shut off from the muscle; the arrow represents the active electrode; the passive electrode is on some distant point to the left of the diagram.

When the active electrode is placed over the muscle, and the current closed, an induced current of opposite polarity appears in the muscle. This virtual pole is diffuse, and its power of causing contraction in healthy muscle therefore less effective than that of the pole placed on the outside of the muscle.

The important practical point emerges that in treating muscles exhibiting R.D. the maximum benefit will be obtained by stimulating the muscle with KCC longitudinally down to its tendon, and that in testing muscles for R.D. the active electrode must be placed as nearly as possible over the motor point.

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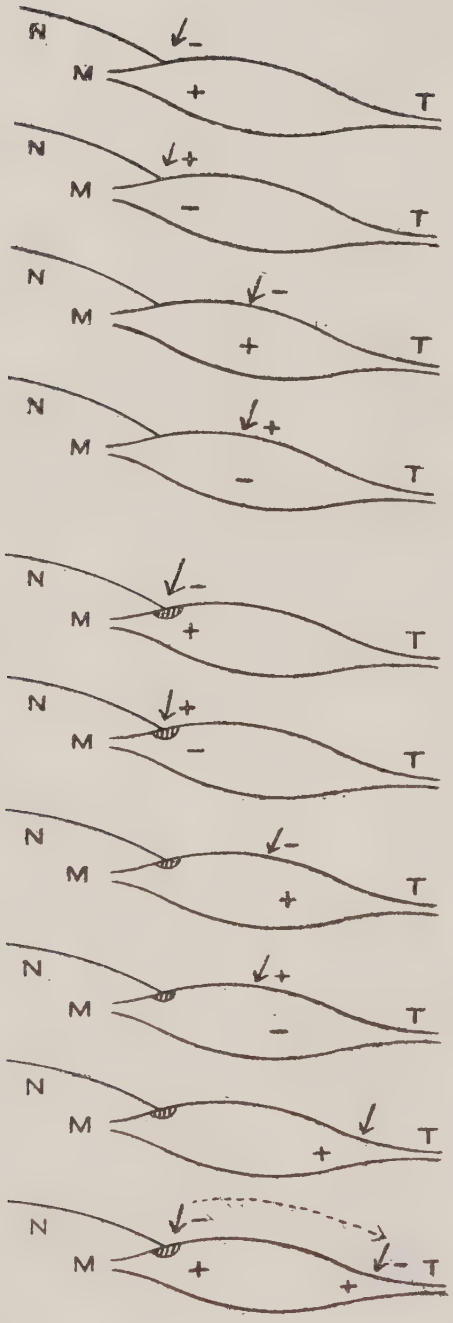
* After Tinel.

FIG. J.




A. *Nerve intact.*

Fig. 1. KCC. Small current required; direct vigorous action of — pole through nerve endings; + inoperative.
V

Fig. 2. ACC. Large current required; diffuse action on muscle from induced — pole; + inoperative.

Fig. 3. KCC. Much larger current required than in 1; diffuse action of — direct on muscle; + inoperative.
Λ

Fig. 4. ACC. Action through induced—direct on muscle; + inoperative (false polar inversion).

B. *Nerve severed.*

Fig. 5. KCC. Slight action only from direct action of — over small portion of muscle.
Λ

Fig. 6. ACC. Greater action through induced — diffused over larger portion of muscle; + inoperative.

Fig. 7. KCC. Similar to 5, but more muscle is directly stimulated.
Λ

Fig. 8. ACC. Similar to 6, but more muscle is stimulated by diffused induced negative.

Fig. 9. KCC. Maximum direct stimulation of muscle by —; longitudinal reaction; + inoperative. (Compare with similar minimal stimulation, Fig. 5.)

Fig. 10. KCC. Method of using longitudinal reaction in the treatment of paralysed muscle: the cathode is swept from M to T, thus directly stimulating the whole muscle.

# INDEX.

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